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AN ANALYTICAL MODEL FOR PREDICTING CROSS-COUNTRY VEHICLE PERFORMANCE

APPENDIX B: VEHICLE PERFORMANCE IN LATERAL AND LONGITUDINAL OBSTACLES (VEGETATION)

VOLUME II: LONGITUDINAL OBSTACLES

57

C. A. Blackmon

D. D. Randolph



July 1968

Sponsored by

Advanced Research Projects Agency

and

Development Directorate

U. S. Army Materiel Command

Service Agency

U. S. Army Materiel Command

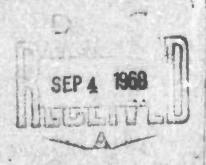
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Project No. I-V-0-25001-A-I31

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FOREWORD

The study reported herein was performed by the U.S. Army Engineer Waterways Experiment Station (WES) for the Office, Secretary of Defense (OSD), Advanced Research Projects Agency (ARPA), and is a portion of one task of the overall Mobility Environmental Research Study (MERS) sponsored by OSD/ARPA for which the WES was the prime contractor and the U. S. Army Materiel Command (AMC) was the service agent. The broad mission of Project MERS was to determine the effects of the various features of the physical environment on the performance of cross-country ground contact vehicles and to provide therefrom data that can be used to improve both the design and employment of such vehicles. A condition of the project was that the data be interpretable in terms of vehicle requirements for Southeast Asia. funds employed for this study were allocated to WES through AMC under ARPA Order No. 400. Some funds for preparation and publication of this report were provided by the Development Directorate, AMC, under Department of the Army Project 1-V-0-25001-A-131, Military Evaluation of Geographic The study was performed during the period June 1964 to November 1965 under the general guidance and supervision of the MERS Branch of the WES, the staff element of WES responsible for the technical management and direction of the MERS program.

This appendix is one of seven to the report entitled An Analytical Model for Predicting Cross-Country Vehicle Performance. These appendixes are:

- A. Instrumentation of Test Vehicles
- B. Vehicle Performance in Lateral and Longitudinal Obstacles (Vegetation)

Volume I: Lateral Obstacles

Volume II: Longitudinal Obstacles

- C. Vehicle Performance in Vertical Obstacles (Surface Geometry)
- D. Performance of Amphibious Vehicles in the Water-Land Interface (Hydrologic Geometry)
- E. Quantification of the Screening Effects of Vegetation on Driver's Vision and Vehicle Speed
- F. Soil-Vehicle Relations on Soft Clay Soils (Surface Composition)
- G. Application of Analytical Model to United States and Thailand Terrains

The study was conducted by personnel of the Area Evaluation Branch, Mobility and Environmental (M&E) Division, under the general supervision of Mr. W. J. Turnbull, Technical Assistant for Soils and Environmental Engineering; Mr. W. G. Shockley, Chief of the M&E Division; Mr. S. J. Knight, Assistant Chief, M&E Division; Mr. A. A. Rula, Chief, MERS Branch; Mr. Warren E. Grabau, Chief, Area Evaluation Branch; and Mr. Jack K. Stoll, Chief, Field Test Section, who was in direct charge of all phases of the study. Personnel of WES technical support elements provided major assistance in the field test program. Data reduction and preparation of plates and tables were accomplished by Messrs. W. T. Willis and V. J. Piazza under the direction of Mr. D. D. Randolph who performed the major portion of the data analysis. This report was written by Messrs. C. A. Blackmon and Randolph.

Directors of the WES during this study and preparation of this report were COL Alex G. Sutton, Jr., CE, and COL John R. Oswalt, Jr., CE. Technical Director was Mr. J. B. Tiffany.

CONTENTS

	Page
FOREWORD	111
NOTATION	vii
CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT	ix
SUMMARY	хi
PART 1: INTRODUCTION	Bl
Background	Bl Bl
PART II: TEST PROGRAM	В3
Vegetation Tested	B3 B11 B14 B14 B15
	B19 B20
PART III: ANALYSIS OF DATA	B22
Single Standing Tree Override Tests	B22 B22 B26 B28 B31
PART IV: CONCLUSIONS AND RECOMMENDATIONS	B35
	B35 B35
TABLES B1-B4	
PIATES RI-RIS	

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NOTATION

- d Clump diameter, in.
- d Stem diameter, in.
- F Maximum horizontal pushbar force, lb
- Fm Average horizontal pushbar force required to fail trees in multiple array, lb
- F Computed average horizontal pushbar force required to fail an array of trees with no crown interference, lb
- h, Pushbar height, in.
- K Constant for each pushbar height
- S Unit fiber stress at the outside fiber of the section, psi
- Wh Work required to fail a bemboo clump, lb-ft
- Wm Work required to fail trees in multiple array, lb-ft
- Work required to override trees in multiple array, lb-ft
- Wp Work required to fail a single standing tree, lb-ft
- W. Work required to override a single standing tree, lb-ft

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CONVERSION FACTORS, BRITISH TO METRIC UNITS OF MEASUREMENT

British units of measurement used in this report can be converted to metric units as follows:

Multiply	Ву	To Obtain
inches	2.54	centimeters
feet	0.3048	meters
miles	1.609344	kilometers
pounds	0.45359237	kilograms
pounds per square inch	0.070307	kilograms per square centimeter
inch-pound	0.011521	meter-kilograms
foot-pounds	0.138255	meter-kilograms
ton	907.185	kilograms

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SUMMARY

A total of 372 tests were conducted with one tracked and one wheeled vehicle at the NASA Marshall Space Flight Center, Miss., Eglin Air Force Base, Fla., Pran Buri. Thailand, and Khon Kaen, Thailand. The general purpose of these tests was to obtain data relating characteristics of longitudinal obstacles to vehicle performance in terms suitable for use in developing that portion of the analy ical model for cross-country performance. The specific purposes were (a) to determine the maximum horizontal force and total work required to override single standing trees of a range of sizes at various speeds and pushbar heights and (b) to determine average horizontal force and total work required to override trees in multiple array. Empirical relations are presented to support the conclusions that pushbar force required to fail trees singly and in multiple array, work required to fail trees singly and in multiple array, and work required to override a single standing tree may be predicted from stem diameter(s). A method is suggested for predicting work required to override trees in multiple array. The results of the tree-felling tests in the Tunguska meteorite area were confirmed, with a single exception noted, and discussed. It is recommended that additional testing be done in areas of soft soil to determine the effect of soil strength on uprooting, and in grass and brush areas to determine the effect of small vegetation on speed.

AN ANALYTICAL MODEL FOR PREDICTING CROSS-COUNTRY VEHICLE PERFORMANCE

APPENDIX B: VEHICLE PERFORMANCE IN LATERAL AND LONGITUDINAL OBSTACLES (VEGETATION)

VOLUME II: LONGITUDINAL OBSTACLES

PART I: INTRODUCTION

Background

- 1. The main text of this report describes the development of an analytical model for predicting the cross-country performance of a vehicle. The model was based on an energy concept within the framework of classical mechanics that requires cause-and-effect relations be established between discrete terrain factors and vehicle response. This volume of Appendix B deals with the effects of a single terrain factor-longitudinal obstacles. The term "obstacle" in general refers to all features of the terrain, except soil, that are inhibitory to vehicle mobility. The obstacle-effects spectrum on vehicle mobility ranges from complete immobilization to minor speed reduction. For the purpose of the overall study, obstacles were categorized according to the direction of motion forced upon a vehicle negotiating the obstacle, i.e. vertical, lateral, or longitudinal.
- 2. Vegetation, such as small trees, shrubs, bushes, grasses, etc., that a vehicle can override causes neither vertical nor lateral motion to any marked degree but creates a resisting force parallel to the longitudinal axis of the vehicle that acts to slow the rate of forward motion, hence the nomen longitudinal obstacles.
- 3. Although very little information has been published on tree override, an empirical relation between felling moment of trees and stem diameter has been published along with some interesting conclusions from treefelling tests in the Tunguska meteorite area in Russia.

Purpose and Scope

4. This appendix describes the longitudinal obstacle tests conducted

in the United States and in Thailand during the period August 1964-November 1965. The general purpose of these tests was to obtain data relating characteristics of longitudinal obstacles to vehicle performance in terms suitable for use in developing that portion of the analytical model for cross-country performance. The specific purposes were (a) to determine the maximum horizontal force and total work required to override single standing trees of a range of sizes at various speeds and pushbar heights and (b) to determine average horizontal force and total work required to override trees in multiple array.

- 5. Two types of tests were originally scheduled--single standing tree override and multiple tree override. When it became apparent that bamboo fit neither of these, a third type was added--bamboo clump override.
- 6. This investigation was limited to trees and bamboo in areas of firm soil.

PART II: TEST PROGRAM

Location and Description of Test Areas

NASA Marshall Space Flight Center

7. Single standing tree override tests and multiple tree override tests were conducted at the NASA Marshall Space Flight Center, Hancock County, Miss. (fig. Bl). The locations of the test sites are shown in fig. B2. The test sites were level to gently sloping (less than 2 percent) and free of surface irregularities; grass and some small bushes were growing on the sites (fig. B3). Trees at the sites were coniferous, hardwood, or coniferous and hardwood mixed, with stem diameters ranging from 0.3 to 13.5 in.* Soils in the NASA area were classified as ML, CL-ML, CL, SC-SM, SM-SC, and SP-SM according to the Unified Soil Classification System (USCS). Average cone index in the 0- to 6-in. layer ranged from 80 to 533, and in the 6- to 12-in. layer from 112 to 750.

Eglin Air Force Base

8. Single standing tree override tests and multiple tree override tests were conducted at the Eglin Air Force Base test area, Fort Walton, Fla. (fig. Bl). The locations of the test sites are shown in fig. B4. The test sites were level to gently sloping (less than 2 percent), were free of surface irregularities except for an occasional stump hole, and supported grans and abundant small understory plants. Trees at the sites were hardwood or hardwood and coniferous mixed (fig. B5). The stem diameters ranged from 1.0 to 13.0 in. The soils were classified as SM or SP-SM according to the USCS. Cone index in the 0- to 6-in. layer ranged from 41 to 132 and in the 6- to 12-in. layer from 60 to 199.

Pran Buri, Thailand

9. Bamboo clump override tests were conducted at the Pran Buri test area (fig. B6). All the bamboo clump override tests were conducted at one test site about 300 ft square (fig. B7). The test area was level and free of surface irregularities (fig. B8). The stem diameter of the bamboo

^{*} A table of factors for converting British units of measurement to metric units is presented on page ix.

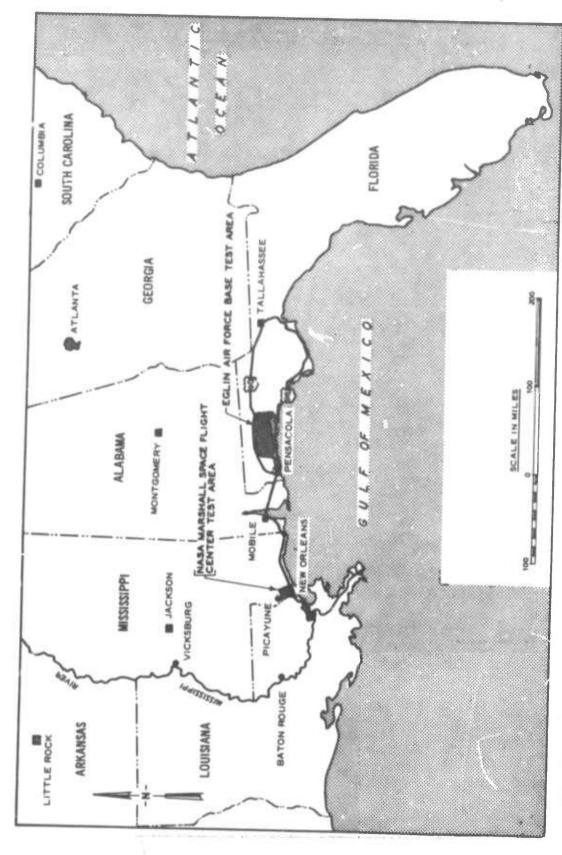


Fig. Bl. Vicinity map, NASA Marshall Space Flight Center and Eglin Air Force Base test areas

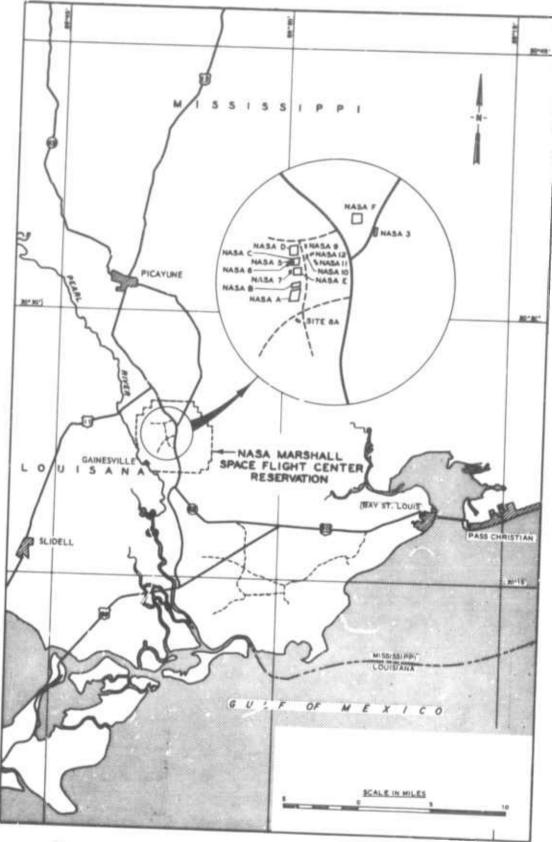


Fig. B2. Location of test sites, NASA Marshall Space Flight Center test area



Fig. B3. NASA Marshall Space Flight Center test area

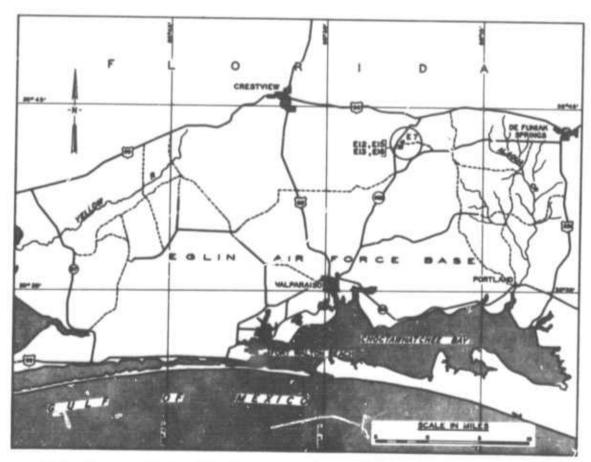


Fig. B4. Location of test sites, Eglin Air Force Base test area

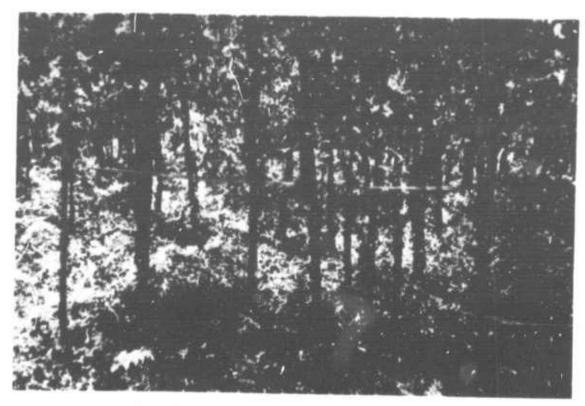


Fig. B5. Eglin Air Force Base test area

ranged from 0.1 to 1.0 in., the clump diameter ranged from 3 to 40 in. at the ground surface, and the number of stems per clump ranged from 10 to 55. The soil was classified as SM in the 0- to 6-in. layer and ML in the 6- to 12-in. layer according to the USCS. The average cone index in the 0- to 6-in. layer ranged from 95 to 174 and in the 6- to 12-in. layer from 112 to 178.

Khon Kaen, Thailand

10. Single standing tree override tests were conducted in the Khon Kaen test area of Thailand (fig. B6). All the tests were conducted at one site about 400 ft square (fig. B7). The test site was level to gently sloping (less than 2 percent), was free of surface irregularities, and supported grass, small broadleaf understory plants, and Heing trees (fig. B9). The stem diameters ranged from 1.8 to 13.0 in. The soil was classified as SM in the 0- to 6-in. layer and as CL-ML in the 6- to 12-in. layer. The cone index ranged from 121 to 209 in the 0- to 6-in. layer and from 120 to 289 in the 6- to 12-in. layer.

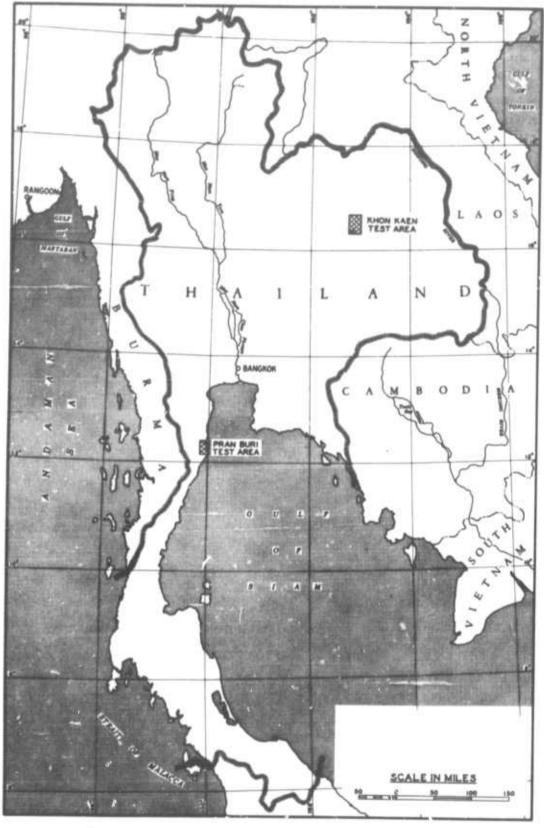


Fig. B6. Vicinity map, Khon Kaen and Pran Buri test areas

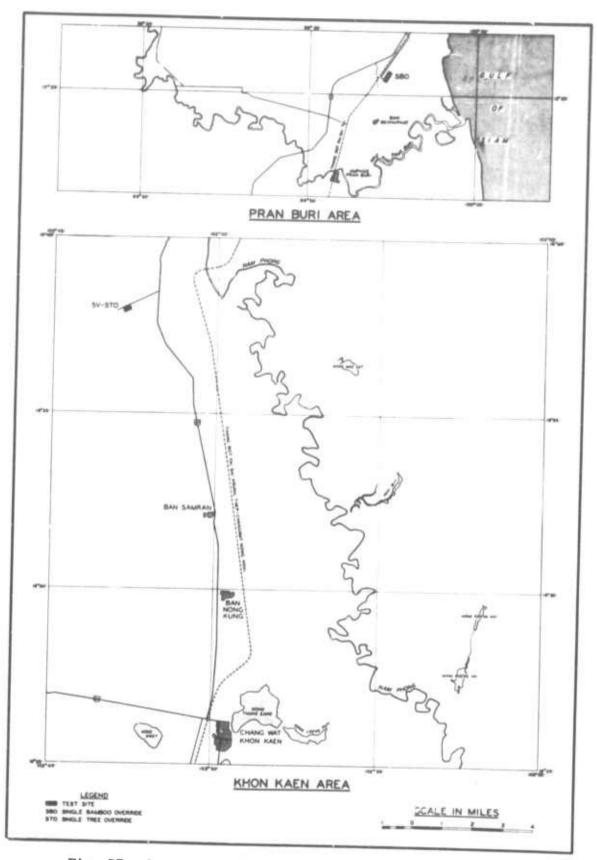


Fig. B7. Location of Pran Buri and Khon Kaen test sites



Fig. B8. Bamboo override test area, Pran Buri, Thailand

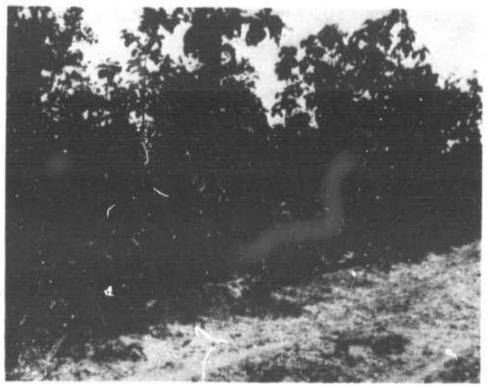


Fig. B9. Single standing tree override test area at Khon Kaen, Thailand

Vehicles Used

ll. Two venicles were used in these tests--an M37 3/4-ton cargo truck and an M113 armored personnel carrier. Pertinent physical characteristics of the vehicles are as follows:

M37 3/4-ton cargo truck	
Test weight, 1b	7350-7645
Tires Size Ply	9:00-16 8
Ground clearance, in.	10.8
Engine Type Brake horsepower	Gasoline 78
Transmission	Manual, synchromesh
Mll3 armored personnel carrier (APC)	
Test weight, 1b	19,515-23,896
Track Contact length, in. Width, in. Shoe, in.	105 15 6
Contact pressure, psi	7.5
Bogies on ground, per side	5
Ground clearance, in.	16.1
Engine Type Brake horsepower	Gasoline 215
Transmission	Hydraulic, single stage multiphase

Photographs of the vehicles are included as figs. BlO and Bll.

12. No comparison of the tree-failing capabilities (tree failure is defined in paragraph 32) of the two vehicles used in the investigation was contemplated as the vehicles were considered only as instruments for testing the vegetation. To this end, a heavy-duty pushbar was fabricated and mounted on each vehicle. The pushbar height of the M37 was fixed at 26 in. (fig. Bl2); the pushbar height of the M113 could be adjusted in 6-in.



Fig. Blo. M37 3/4-ton truck

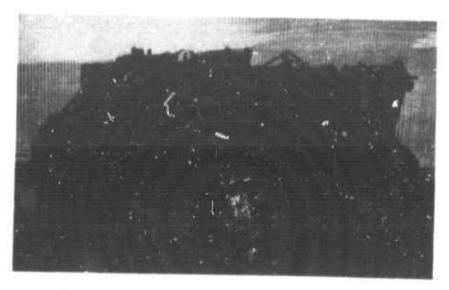


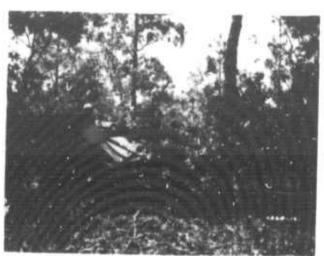
Fig. Bll. Mll3 armored personnel carrier

increments between 20 and 56 in. (fig. Bl3). Both vehicles were equipped with fairly elaborate measuring and recording systems.*

^{*} This instrumentation is discussed in detail in "An Analytical Model for Predicting Cross-Country Vehicle Performance; Appendix A: Instrumentation of Test Vehicles," by B. O. Benn and M. Keown, Technical Report No. 3-783, July 1967, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Fig. Bl2. Pushbar mounted on M37 3/4-ton truck





a. Pushbar at 32 in.

b. Pushbar at 56 in.

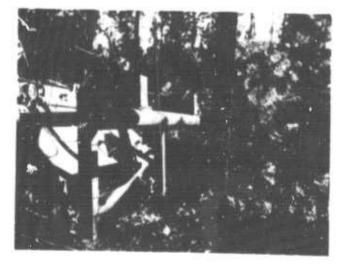


Fig. Bl3. Pushbar mounted on Ml13 armored personnel carrier

Vegetation Tested

13. The vegetation tested consisted of coniferous and hardwood trees, and bamboo grass. Each tree overridden was identified by common name. The conifers included pine and cypress; the hardwoods included oak, hawthorn, and the Heing trees of Thailand. Bamboo grass was treated separately in this investigation.

Types of Tests Conducted

14. Although the tests were basically alike in that they sought the answer to the question "How much force and work are required to override a tree or group of trees, and to what measured physical characteristic of the tree can these be related?", there were some differences in the obstacles per se and the conduct of the tests. The types and number of tests in each of the four areas are listed below. It can be seen that the major effort was devoted to single standing tree override tests (333 tests in three areas).

Location	Single Standing Tree Override	Bamboo Clump Override	Multiple Tree Override	Total
NASA	196	0	12	208
Eglin	78	0	3	81
Pran Buri	0	24	0	24
Khon Kaen	59	0	0	59
	Total 333	24	15	372

Single standing tree override tests

15. Single standing tree override tests were, as the name implies, conducted against one live standing tree with adjacent trees removed so that the vehicle could approach the tree in a straight line and the tree could fall without interference. These tests were conducted at speeds ranging from 0.0 to 17.1 mph and at five pushbar heights ranging from 20 to 56 in.

Bamboo clump override tests

- 16. Bamboo clump override tests were conducted against single clumps of bamboo carefully selected so that the vehicle could approach in a straight line and the bamboo clump could fall without interference. These tests were conducted with a single pushbar height (26 in.) and at speeds of approximately 2 mph with the exception of two tests at higher speeds.

 Multiple tree override tests
- 17. Multiple tree override tests were conducted against an array of trees that permitted interference of the crowns as the trees were overridden. An approach strip was cleared so that the vehicle could attain the desired speed before entering the test site. These tests were conducted at approximately 2 mph and at a single pushbar height (26 in.).

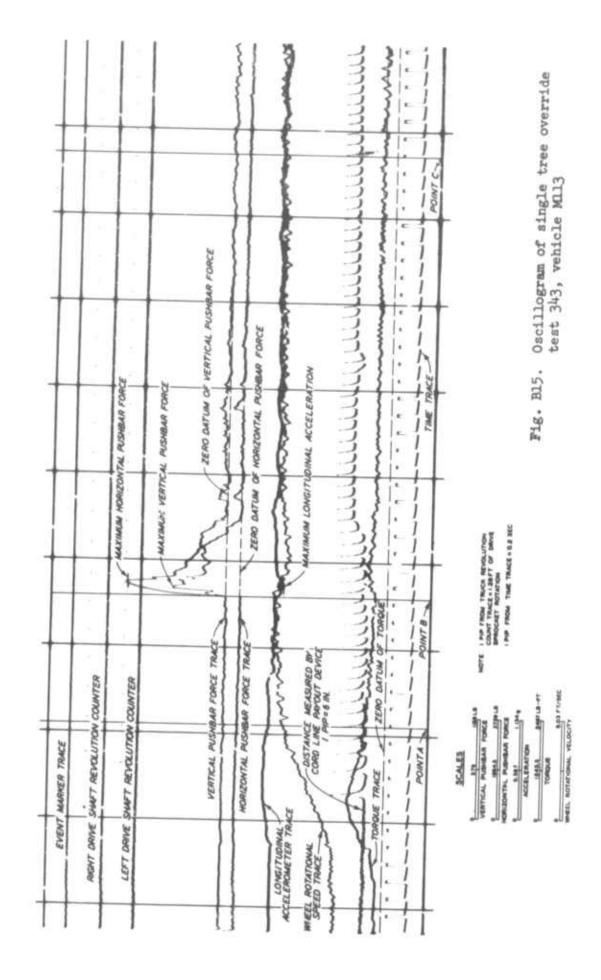
Test Procedures and Data Obtained

Single standing tree override tests

18. Procedures. The vehicle accelerated to the desired contact speed at least 20 ft before striking the tree (fig. Bl4). The driver



Fig. Bl4. Pushbar striking tree in single standing tree override test



attempted to maintain this speed until the vehicle had completely overridden the tree.

19. Data obtained. By means of electronic instrumentation installed on the test vehicle, continuous measurements of horizontal pushbar force, distance actually traveled, and time were made and recorded. In addition, for some tests vertical pushbar force, drive line torque, drive shaft revolutions, and wheel or track rotational speed and longitudinal acceleration were measured and recorded. An example of an oscillogram record, for test 343, is shown in fig. Bl5. A summary of the data read directly from the oscillogram, i.e. maximum horizontal pushbar force, maximum vertical pushbar force, and maximum longitudinal acceleration, and the data computed from the oscillogram, i.e. contact speed, work required to fail the tree, work required to override tree, and maximum tractive force is given in table Bl.

Bamboo clump override tests

- 20. Procedures. The vehicle approached the clump at the desired speed and the driver attempted to maintain this speed until the vehicle had overridden the clump (fig. Bl6).
- 21. <u>Data obtained</u>. Instrumentation for the bamboo clump override tests was limited to only that needed to determine maximum horizontal pushbar force, work required to fail the clump, vehicle speed, and maximum longitudinal acceleration. A summary of these data is given in table B2.

Multiple tree override tests

22. <u>Procedures</u>. The vehicle approached the test site at a speed of approximately 2 mph in its

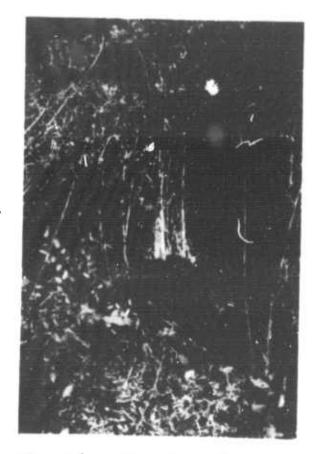
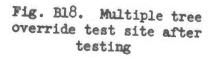


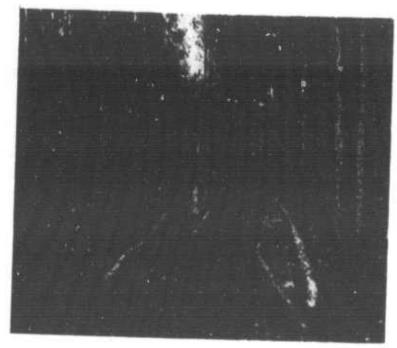
Fig. Bl6. Bamboo clump after being overridden

lowest gear and the driver attempted to maintain this speed while proceeding in as straight a line as possible through the test site overriding all trees in the path of the vehicle (fig. Bl7). Fig. Bl8 illustrates a multiple tree override test site after testing.



Fig. Bl7. Multiple tree override test. Note crown interference





23. <u>Data obtained</u>. The instrumentation on the vehicle measured and recorded horizontal pushbar force, time, distance actually traveled, driveshaft revolutions, longitudinal acceleration, and drive-line torque. A summary of the data read or computed from the oscillogram is given in table B3.

Vegetation Data Obtained

Single standing trees

- 24. For convenience in conducting the tests, ensuring that all necessary data were secured, and collating the test data, vegetation data, and soil data, each tree utilized in the single standing tree override tests was given a specific number. For each test the vegetation data consisted of the common name of tree, tree height, branching height, stem diameter at 42 in. aboveground, crown diameter, and mode of failure, and observations of unusual occurrences during the test. These data are given in table Bl. Bamboo clumps
- 25. Bamboo did not fall in the category of either conifers or hardwoods, and the tests were representative of neither single standing tree override nor multiple tree override. Various vegetation data were obtained during the course of the bamboo clump override investigation; however, only number of stems, stem diameter, and clump diameter are included in this report. These data are summarized in table B2.

Trees in multiple array

26. Vegetation data obtained for the multiple tree override tests included common names of trees, height, stem diameter, structural cell* diameter, and mean tree spacing. A planimetric map of each multiple tree

^{*} The structural cell concept with its derivatives, mean tree spacing, nearest neighbor distance, etc., has been explored with some intensity by the U.S. Army Engineer Waterways Experiment Station. The concept is described in "Quantitative Physiognomic Analysis of the Vegetation of the Florida Everglades," by H. L. Mills, Contract Report No. 3-72, 1963, U.S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.; prepared by Marshall University, Huntington, W. Va.

override test site was prepared; an example is shown in fig. Bl9. Immediately after each test the number of trees actually overridden was determined. These data are summarized in table B3.

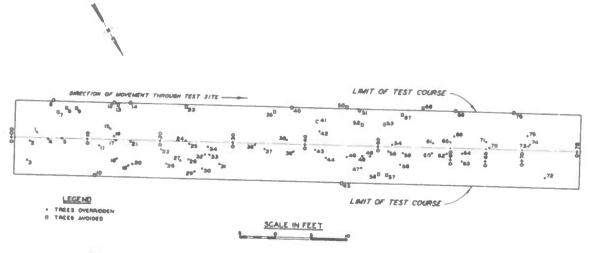


Fig. Bl9. Flanimetric map of multiple tree override, test site NASA 6

Soil Data Obtained

27. During this study the primary reasons for obtaining soil data were to describe the test areas adequately and to ensure that there was no radical change in soil strength or composition at a test site. The effect of soil characteristics on the force required to bend or shear a tree stem appeared nil to the experimenters (possibly because the soils in the test area were firm), and while an effect of soil characteristics on the force required to uproot a tree might be hypothesized, any investigation of such effect was beyond the scope of this study. However, since soil strength and composition are necessary to describe a test area, and for possible, if indeed not probable, future use, the soil data discussed in the following paragraphs are included in this report.

28. Cone indexes were measured at the surface and at 3-in. vertical increments to a depth of 30 in. around the base of each tree used in the single standing tree override tests, to a depth of 24 in. around the base

of each bamboo clump, and to a depth of 18 in. along the path of the vehicle in the multiple tree override tests. The average cone indexes for each 6-in. layer are shown in tables B1, B2, and B3, respectively. Moisture content

29. Average moisture content was determined for the 0- to 6-in., 6. to 12-in., and 12- to 18-in. soil layers for the area around the base of each tree used in the single standing tree override tests. A summary of these data is included in table Bl. Moisture content was determined somewhat less frequently for the multiple tree override tests (table B3) and not at all for the bamboo clump override tests.

Soil samples

30. Samples for classification of the soil according to the USCS were obtained from the 0- to 6-in., 6- to 12-in., and 12- to 18-in. soil layers around the base of each tree used in the single standing tree override tests, and from the 0- to 6-in. and 6- to 12-in. soil layers along the path of the vehicle in the multiple tree override tests. A summary of these data is shown in tables Bl and B3, respectively. Because prior reconnaissance had shown the near uniformity of the soil in the area where the bamboo clump override tests were conducted, additional samples for laboratory analysis were not taken at the time of testing. As a matter of record, the USCS soil type in the area of the bamboo clumps is shown below.

Layer	USCS Type	Name
0- to 6-in.	SM	Silty sand
6- to 12-in.	MI,	Sandy sil+

PART III: ANALYSIS OF DATA

31. The data collected in this test program are analyzed under four headings: Single Standing Tree Override Tests, Bamboo Clump Override Tests, Multiple Tree Override Tests, and Notes, Observations, and Other Data Considered. The conditions and assumptions upon which the analysis is based are described briefly in the following section.

Basis of Analysis

32. From a study of the results of the single standing tree override tests and a study of findings in other programs it was determined that the stem diameter was the tree characteristic that best correlated with the vehicle-tree interaction measurements; hence, stem diameter was selected as the independent variable to represent the tree in the analysis. It was considered that tree failure had occurred when uprooting of the tree, shear of stem, or deformation of the tree terminated the horizontal resistance to the pushbar. Other special considerations peculiar to a particular section of the analysis are discussed in the appropriate section.

Single Standing Tree Override Tests

Maximum horizontal pushbar force

33. Data from the tests of hardwoods and conifers at contact speeds of less than 4 mph and at pushbar heights of 20, 26, 32 and 38, and 56 in. are shown in plates B1, B2, B3, and B4, respectively. The dashed lines in these plates were derived by treating the tree as a contilever beam. The fiber-stress equation states that the resisting moment at any cross section of a beam is equal to the unit stress (S_m) times the moment of inertia of the cross section with respect to the neutral axis divided by the distance from the neutral axis to the outermost fiber. In applying this equation to a tree, the resisting moment is the product of the horizontal pushbar force and pushbar height $(F_h - h_p)$, the moment of inertia of a cross section of a tree stem is $\pi d_s^4/64$, and the distance from the neutral axis to the

outermost fiber is $d_{\rm s}/2$; the equation can be written as

$$F_{h} \cdot h_{p} = \frac{S_{m} \frac{\pi d_{s}^{1}}{64}}{\frac{d_{s}}{2}}$$
 (B1)

34. The ultimate unit stress for most of the trees overridden was approximately 7500 psi.* Substituting 7500 psi for the unit stress, the equation is reduced to

(For 20-in. pushbar height)
$$F_h = 36.8d_s^3$$
 (B2)

(For 26-in. pushbar height)
$$F_h = 28.3d_s^3$$
 (B3)

(For 38-in. pushbar height)
$$F_h = 19.4d_s^3$$
 (B4)

(For 56-in. pushbar height)
$$F_h = 13.1d_s^3$$
 (B5)

In plates Bl-B4 note that although these are not lines of best fit, they do agree with the data points quite well. Two reasons are suggested for the variations:

- a. The 7500-psi unit stress is only an approximate value.
- b. The pushbar height is only an approximation of the length of the moment arm. In more than 50 percent of the tests, the failure occurred in the roots. (See discussion of number and types of failures, paragraph 51.)
- 35. The solid lines in plates B1-B4 represent the parallel lines of visual best fit. The equations of these curves are

(For 20-in. pushbar height)
$$F_h = 30.0d_s^3$$
 (B6)

(For 26-in. pushbar height)
$$F_h = 27.0d_s^3$$
 (B7)

^{*} U.S. Department of Agriculture, "Wood Handbook," June 1940, Forest Products Laboratory, Washington, D. C.

(For 32- and 38-in. pushbar heights)
$$F_h = 22.0d_s^3$$
 (B8)

(For 56-in. pushbar height)
$$F_h = 15.0d_s^3$$
 (B9)

It can be seen in plates Bl-B4 that these curves fit the data points slightly better, but it is also apparent that the difference in the two approaches is small.

36. Thus, within the range of conditions tested, on both a rational and an empirical basis, it is apparent that the maximum horizontal pushbar force required to fail a tree can be expressed as a function of stem diameter by the following general equation

$$F_{h} = Kd_{s}^{3}$$
 (Blo)

where K is a constant for each pushbar height.

37. Data from the tests of single standing trees at vehicle speeds of 4 to 17 mph and pushbar heights of 20 and 38 in. are shown in plate B5. Again, the empirical lines of best fit are shown as solid lines, and the theoretical (slow speed) values for the two pushbar heights are shown by the dashed lines. All but one of the data points fall above the respective theoretical curves, indicating that dynamic factors influence the maximum horizontal pushbar force-speed relation. It is conceivable that additional tests might lead to a "dynamic correction factor" as a function of speed; however, careful examination of the data collected in this program revealed that while there were readily apparent differences between the forces recorded during the tests at less than 4 mph and those recorded at 4 to 17 mph, the tests within each group disclosed no discernible pattern. On this basis it appears that predictions of the maximum horizontal force required to fail a tree at speeds of 4 to 17 mph should be made using the empirical curves.

Work required to fail a single standing tree

38. The work required to fail a single standing tree (W_p) was computed from the horizontal pushbar force and distance measurements recorded

on the oscillogram and was plotted against the stem diameter of the tree overridden. The results of the tests of coniferous trees in the United States, hardwood trees in the United States, and hardwood trees in Thailand are shown in plates B6, B7, and B8, respectively. Note that a single curve appears to fit the date points on all three of these plots reasonably well. It can be seen that for the range of tree sizes and varieties tested, the work required to fail a single standing tree can be considered independent of tree type or geographical location and can be expressed as a function of stem diameter by the equation

$$W_{\rm p} = 56.0d_{\rm s}^3$$
 (B11)

Work required to override a single standing tree

39. While the mathematical computations for the total work performed by the pushbar are precise and the relation established is clear, it must be borne in mind that the work performed by the pushbar is only a part of the total work performed by the vehicle. The pushbar, for instance, is unaffected by the frictional drag of getation on the undercarriage of the vehicle, and the vehicle obviously does at least a modicum of work in propelling itself, even in the absence of vegetation. To this end, the parameter, "work required to override a single standing tree (W_+) ," was defined as the total work done by the vehicle less that amount of work occasioned by motion resistance due to factors other than the tree itself, i.e. slope, soil, grass, etc. The value of this parameter was computed from the torque and distance traces on the oscillogram. The average torque at a constant speed in the approach lane was considered to be necessary to propel the vehicle and was subtracted from the torque recorded while the vehicle was overriding the tree. A plot of work required to override a single standing tree versus stem diameter is shown in plate B9. There is somewhat more scatter on this plot than is desired, but noting that tests from the United States and Thailand, of hardwood and conifers, at speeds less than 4 mph and from 4 to 12 mph are all incorporated, the scatter does not appear excessive. The curve drawn through the data points is parallel to the curve relating work required to fail a single standing tree to stem

diameter, thus permitting the latter value to be converted into work required to override a single standing tree by applying a constant, as follows

$$W_{t} = 100.0d_{s}^{3}$$
 (B12)

$$W_{t} = 1.786W_{p}$$
 (B13)

Distance required to fail a single standing tree

40. All attempts to relate vehicle travel distance required to fail a single standing tree with tree characteristics, force measurements, or pushbar heights were unsuccessful. A summary of the distances the vehicles traveled to fail trees with the pushbar at heights of 20, 26, and 32 in. is given in table B4. From the table it can be seen that with a 20-in.-high pushbar the distance required to fail a single standing tree ranged from 2.1 to 9.4 ft, and the average distance was 5.67 ft; with a 26-in.-high pushbar the distances ranged from 3.5 to 8.2 ft and the average distance was 5.71 ft; and with a 32-in.-high pushbar the distances ranged from 3.0 to 8.7 ft and the average distance was 5.93 ft. The small increase in average distance as the pushbar height was increased from 20 to 32 in. is judged to be insignificant. Since the height of the bumper or leading edge of nearly all military vehicles falls within the 20- to 32-in. range, the average distance required to fail a tree with a military vehicle is considered to be the average of all tests or about 5.8 ft.

Bamboo Override Tests

41. Although a bamboo clump might appear, superficially at least, to be either a special case of a single standing tree or a multiple array of small trees, the test results were not compatible with those of either category. Plots of maximum horizontal pushbar force and pushbar work versus stem diameter, number of stems, clump diameter, and various combinations were studied to determine which feature of the bamboo clump would

give the best correlations. It was found that the plots with clump diameter as the independent variable yielded the least scatter; this is not unreasonable when it is considered that in all tests the bamboo clumps failed by uprooting, as previously illustrated (fig. Bl6, page Bl7).

42. The M37 truck became immobilized in four of the 24 bamboo override tests. In each of these four tests, the bamboo clump was actually failed, but when the vehicle attempted to completely override the clump at a slow speed, the front wheels of the vehicle were lifted clear of the ground and there was insufficient traction for the rear wheels to furnish the necessary forward thrust. In other tests, considerable wheel slip occurred as the vehicle was overriding the tree, resulting in torque measurements that were not amenable to analysis, hence the analysis is limited to maximum horizontal pushbar force required to fail a bamboo clump and work required to fail a bamboo clump as functions of clump diameter. The relations obtained are discussed in the following paragraphs.

Maximum horizontal pushbar force

43. A plot of the maximum horizontal pushbar force (F_h) required to fail a bamboo clump versus clump diameter is given in plate BlO. The data from the four tests in which immobilization occurred are shown by closed symbols and are believed to be valid waints on this plot since the immobilizations occurred after the pushbar has failed the clump. The curve drawn represents the line of visual best fit without reference to the data point from test 246. Notably, this test was conducted at the lowest speed and the bamboo clump overridden had the fewest stems of any in the program. This seems to point out that factors other than clump diameter, i.e. number of stems, speed of impact, and stem diameter, may significantly affect the maximum horizontal pushbar force. However, for the tests conducted, the equation of the curve in plate BlO

$$F_h = 2.1d_c^{2.15}$$
 (B14)

represents a reasonable approximation of the force required to fail a bamboo clump.

Work required to fail a bamboo clump

during the bamboo clump override tests were not remunerative; hence, the work required to override a bamboo clump could not be determined from the available data. Nevertheless, the intermediate value, work required to fail a bamboo clump (W_b), was studied and a plot of these values versus clump diameter is shown in plate Bll. The data from the tests resulting in immobilizations are shown by closed symbols and are held to be valid points. The curve drawn is the line of bost visual fit, again without reference to test 246. The scatter of the data is less than that on the plot of horizontal pushbar force versus clump diameter, suggesting that work required to fail the clump is less affected by speed than is horizontal pushbar force. The equation of the curve in plate Bl.

$$W_b = 3.41d_c^{2.15}$$
 (B15)

provides an acceptable method of predicting the work required to fail a bamboo clump within the range of sizes tested.

Multiple Tree Override Tests

45. Obviously it takes more effort to override trees spaced closely together than when each tree can fall free of interference by its neighbors. The increase is due principally to the interference of crowns as shown in fig. B18, page B18. The study of this increase was the principal purpose of the multiple tree override tests.

Average horizontal pushbar force

46. A plot of average measured horizontal pushbar force required to fail trees in multiple array (F_m) versus the average horizontal pushbar force that would have been required to fail the same combination of trees severally (F_g) as computed from the relations established in the single standing tree override tests is shown in plate B12. A sample computation of average pushbar force required for test 12 is shown as follows.

Distance ft	Tree	Stem Diameter (d _s), in.		Required to Fail (Wp), lb-ft
25	85 86 103 104 105 108 109	5.7 3.5 3.1 5.9 3.6 6.1 4.2		10,371 2,401 1,668 11,501 2,613 12,711 4,149
			Total	45,414

$$F_s = \frac{45,414}{25} = 1817 \text{ lb}$$

It can be seen in plate Bl2 that the average force requirement for trees in multiple array was significantly greater than that required to fail the trees severally, even when the latter was as low as 136 lb. It can also be seen that the increase in average force required becomes greater as the computed average force required to fail the trees separately increases. The scatter of data appears well within the limit of experimental error and the equation given in this plot

$$F_{\rm m} = 0.66F_{\rm s}^{1.127} \tag{B16}$$

appears to adequately define the average horizontal force demand of trees in multiple array within the limits encountered in this test program.

Work required to fail trees in multiple array

47. A plot of measured work required to fail trees in multiple array (W_m) versus the summation of the work required to fail the same combination of trees severally as computed from relations developed in single standing tree override tests is shown in plate B13. In this plot it can be seen that the total measured work required to fail trees in multiple array was significantly greater than the total work required to fail the same combination of trees severally, and that the increase in work required by trees in multiple array became greater as the computed work required increased.

Again, the scatter of data appears quite reasonable and the equation given in this plate

$$W_{\rm m} = 0.6 \left[\sum_{\rm l \to n} (W_{\rm p}) \right]^{1.088} \tag{B17}$$

satisfactorily expresses the relation between work required to fail trees in multiple array and the summation of the work required to fail the same combination of trees individually.

48. Since the work required to fail a single standing tree (\mathbf{w}_{p} in the equation above) has been shown to be a function of the stem diameter, combining equation Bl1 and equation Bl7 gives

$$W_{\rm m} = 0.6 \left[\sum_{\rm l \to n} (56d_{\rm s}^3) \right]^{1.088}$$
 (B18)

thus expressing work required to fail trees in multiple array as an exponential function of the stem diameters.

Work required to override trees in multiple array

- 49. The work required to override trees in multiple array is, of course, greater than the work required to fail trees in multiple array for the same reasons that applied to single standing trees. Regrettably, the available data do not permit an empirical evaluation of the work required to override trees in multiple array. Torque meters were not available until late in the test program. Therefore, torque measurements were obtained only for tests 455, 453, and 459. However, because of wheel slip during the test and errors made in calibrations, the torque measurements were not reliable. Nevertheless, it is possible to make some inferences from the relations established herein.
- 50. It has been shown that the work required to override a single standing tree expressed as a function of the stem diameter (equation B12) is linearly related to the work required to fail a single standing tree expressed as a function of the stem diameter (equation B11), and may be equally as well expressed as a constant times the work required to fail a single standing tree (equation B13). In the absence of data indicating

otherwise, it appears that the same constant might be used to relate work required to fail trees in multiple array to work required to override trees in multiple array (W_0); then

$$W_0 = 1.786W_m$$
 (B19)

and substituting in equation B18 and reducing

$$W_{o} = 1.07 \left[\sum_{l \to n}^{\Sigma} (56d_{s}^{3}) \right]^{1.088}$$
 (B20)

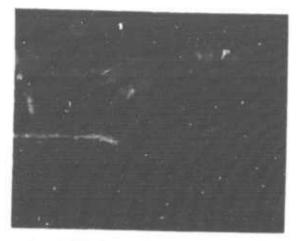
Notes, Observations, and Other Data Considered

Tree failure modes

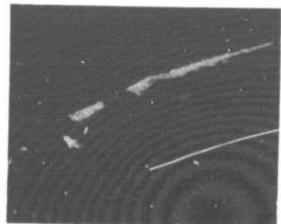
51. Illustrated in fig. B20 are the five tree failure modes exhibited in the override tests: type 1, in which the stem failed in compression; type 2, in which the stem failed in tension; type 3, in which the roots failed in tension and the soil in shear; type 4, in which the roots failed in tension without pronounced failure of the soil; and type 5, in which the stem deformed elastically. Types 1, 2, and 5 indicate that the root-soil system was stronger than the stem. Types 3 and 4 indicate that the stem was stronger than the root-soil system. The number of failures of each type is given in the following tabulation:

_	Туре	No. of Failures
0	No failure indicated	11
1	Compression (stem)	10
2	Tension (stem)	37
3	Shear (soil) and tension (root)	215
4	Tension (root)	12
5	Elastic (stem)	41

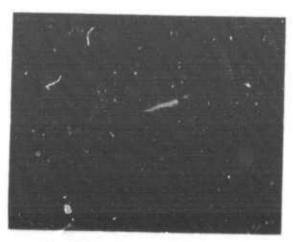
There was no apparent indication that the type of failure, per se, significantly affected the test results.



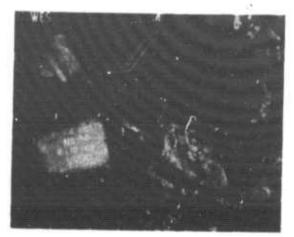
a. Type 1, compression (stem)



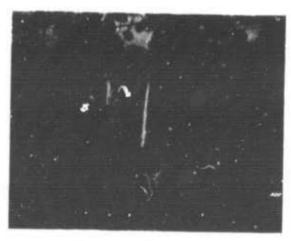
b. Type 2, tension (stem)



c. Type 3, tension (root) and shear (soil)



d. Type 4, tension (root)



e. Type 5, elastic (stem)



Effect of soil conditions

52. Within the range of soil conditions encountered in this progr 1, the effects of the soil type, soil strength, or moisture content could not be isolated. While it is believed that the method of analysis, i.e. pushbar force and torque minus motion resistance, satisfactorily eliminated or compensated for soil conditions insofar as the vehicle was concerned, there remains the fact that 215 single standing tree override tests, as shown in the preceding tabulation, resulted in soil shear and all of the bamboo clump override tests resulted in soil shear. It is axiomatic that soil shear strength varies inversely with moisture content, and it would be reasonable to expect the soil condition to have a significant effect on force required to fail or override a tree when the failure occurred in the soil. For instance, the tabulation in the following paragraph indicates a considerable difference in felling moments in dry and moist soils in the Tunguska Meteorite Area; however, as previously stated, the test areas used in the program reported herein were chosen to minimize the effect of soil strength on the vehicle, i.e. no significant rutting. It might be reasoned that when the soil is sufficiently strong, an increase in strength does not result in a significant increase in vehicle performance; then the increase in resistance to uprooting a tree would also be insignificant. This is, however, beyond the scope of this test program.

Data from other sources

53. In a report of the preliminary results from the 1961 combined Tunguska Meteorite Expedition, Florenskii* described a series of tests in which the felling moment of trees was determined by means of a winch and a dynamometer. Results of these tests yielded the following conclusions:

(a) there is no relation between felling moment and species and age of a tree, (b) there is a distinct relation between moment and tree diameter, analytically nicely described by a parabola, (c) the parabolas are completely identical for fine and rocky soils, (d) the scatter of the data diminishes in inverse proportion to the diameter of the tree, (e) the felling moments of trees in dry soils are significantly greater than the

^{*} K. P. Florenskii, "Preliminary Results from the 1961 Combined Tunguska Meteorite Expedition," Meteoritica, Vol XXIII, Moscow, 1963.

felling moments of trees in moist, riverside soils. Each of the first four conclusions was verified by single tree override tests conducted in the United States and in Thailand. Florenskii's fifth conclusion could neither be confirmed nor denied; however, the magnitude of variation he reported is interesting and is summarized in the following tabulation.

Tree	Average 1	Felling Mome	ent, lb-ft
Diameter in.	Moist Soil	Dry Soil	Percent Increase
5.9	5,100	8,000	57
7.9	10,800	16,600	54
9.8	20,200	26,700	37
11.8	30,400	39,800	31

PART IV: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

54. Based on the analysis of the data reported herein, and subject to the limits imposed by these data, the following conclusions are offered:

- a. The maximum horizontal pushbar force required to fail a single standing tree may be predicted from the stem diameter, vehicle speed, and pushbar height (paragraphs 33-36).
- b. The work required to fail a single standing tree may be predicted from the stem diameter (paragraph 38).
- c. The work required to override a single standing tree may be predicted from the stem diameter (paragraph 39).
- d. The average horizontal pushbar force required to fail trees in multiple array may be predicted from the stem diameter (paragraph 46).
- e. The work required to fail trees in multiple array may be predicted from the stem diameter (paragraphs 47-48).
- f. The maximum horizontal pushbar force required to fail a bamboo clump may be predicted from clump diameter (paragraph 43).
- g. The work required to fail a bamboo clump may be predicted from stem diameter (paragraph 44).

Recommendations

55. It is recommended that:

- a. Additional single standing tree override tests be conducted in areas of low soil strength to determine the effect, if any, of soil strength on the force required to uproot a tree.
- <u>b.</u> Additional multiple tree override tests be performed to extend the relations already developed and to develop empirically the relation of work required to override trees in multiple array and stem diameters.
- Both single vegetation stem override tests and multiple vegetation stem override tests be conducted in areas of grass and brush to develop override-speed relations.
- d. Additional bamboo override tests be performed in other areas with a vehicle capable of completely overriding the bamboo clumps.

Table Bl

						m-										Pushhar			
Test /ehicle	Site No.4	Test No.	Tes	t Date	Tree	Tree Type (Common Name)	Branch- ing Height _ft	Tree Height ft	Crown Diame'er ft	Diameter 42 ln. Above- ground, in.	Work Required to Fall Tree, 1b-ft	Work Required to Override Tree, 1b-ft	Maximum Tractive Force, 1b	Hax um Horiz tal Push, r Porce, lb	Maximum Vertical Pushbar Force, 1b	Height Above- ground in.	Speed at Contact mph	Maximum Longitudinal Acceleration	Mode o
M27	MASA-D	26		10/1												Soft	wood Tree	s, United Sta	tes
M+7	RASA-C	25	Aug	1964	4 4	Pine Pine	3	7	3	1.2	141	0-0	0-0	74	0-0	56	0.0	**	Elastic
н 7	NASA-D	28	Aug		42	Pine	5	11	3	1.6	178 98	**	4.0	57	**	26	0.0	0.0	Elastic
M37	E-7	4 39	May	1964	75	Plne	7	14	5	1.7	447	731	1 317	48	0.0	26	0.0	1-6	Elastic
M 77	MASA-C	1	Aug	1964	1	Plne		12	l _L	1.8	339	134	1,317	237	**	26	1.5	0.0	Elastic
M37	E-7	425	May	1964	60	Plne	1	4.5	7	1.8	473	703	1,686	155 226	**	26	0.0		Elastic
M37	NASA-D	5#	Aug		łą.ią	Pine	1	1.3	5	2.0	281		0.0	231	**	26 26	0.0	0.0	Elastic
M37	E-7	438	May		74	Pine	7	1.4	5	2.0	637	1,378	1,451	302	**	26	1.8	0.1	Elastic Elastic
437 437	MASA-D	26	Aug	1964	40	Pine	6	14	3	2.2	400	**	0-0	208	10-0	26	0.0	a e	Tension
187	E-7	19	Aug	1964	59	Pine	1	13	8	2.3	307	••	**	166	0.0	26	0.0	0.0	Elastic
137	E-7	h 32	Kay	1964	68	Pine Pine	0.5	16	10	2.5	1,053	1 617	1,928	594	0-0	26	1.5	0.08	Elasti~
137	C	6	Aug	1964	6	Pine	11	40	14	2.6	990	1,396	1,490	505	44	26	1 9	0.09	Elastic
137	MASA-D	50	Aug	19%	38	Pine	7	15	5	2.7	877	**	**	655	**	26	0 0	0-0	Compress
137	MASA-C	15	Aug	1964	16	Plne	5	14	8	3.0	1,260	9-9	**	511 615	**	26	0.0	**	Elastic
137	E-7	#55	Mny	1964	58	Pine	0.3	50	8	3.0	1,368	1,831	1,912	826	**	26 26	0.0	0.05	Elastic
137	E-7	431A	May	1964	67	Pine	15	25	λ_{b}	3.0	1,720	2,177	2, 24	939	**	26	1.5	0.09	Elastic
37	MASA-D	55	Aug	1964	1	Plne	6	19	7	3.2	1,535	••	**	620	**	26	0.0	**	Tension Elastic
B7	MASA-D	27	Aug	1964	41	Pine	6	55	6	3.4	2.544	0.0	**	1,249	**	26	0.0	**	Tension
137	E-7	435	Hny	1,464	69	Pine	I ₄	27	10	3.4	1,676	1,907	2,083	1,183	**	26	1.8	0.12	Shear (s
137	E-7	442	May	1964	78	Pine	7	35	10	3.4	2,657	4,648	2,421	1,456	**				Tension
37	MASA-C	9	Aug	1464	9	Pine	23	34	5	3.5	2,544	**	00	1,472	**	26 26	0.0	0.11	Tension
•7	NASA-C	16	Aug	1964	18	Plne	6	13	10	3.5	1,615	0-0	9-9	889	0-0	26	0.0	**	Tension
37	E-7	424	Hny	1964	59	Plne	1	55	10	3.5	1,876	2,047	2,179	988		26	1.5	0.12	Elastic Elastic
37	NASA-C	17	Aug	196h	15	Pine	8	19	10	3.6	2,607	0-0	**	1,219	••	26	0.0	**	Tension
37	MASA-C	13	Aug	1964	13	Pine	6	24	9	3.9	2,850	**	**	1,163	**	26	0.0		Shear (s
37	E-7	437	Hny	1964	73	Pins	**	**	5	3.9	3,096	3 018	0.000						Tension
37	NASA-C	7	Aug	1964	7	Pine	**	3.1	348			3,918	2,285	1,302	**	26	1.7	0.30	Elastic
	NASA-B							31	24	4.0	2,257	**	0.0	1,436	**	56	0.0	40	Shear (s Tension
.13				1964	46	Pine	0.0	43	12	4.0	Ť	0-0	0-0	1,500	230	56	0. C	**	Tension
13	MASA-B			1964	47	Pine	16	la la	1,5	4.0	†	**	**	1,150	475	56	0.0	**	Shear (s Tension
				1964	5	P1ne	18	38	10	4.1	3,290	**	0-0	1,934	* *	26	0.0		Shear (se Tension
7	MASA-C			1964	12	Pine	7	23	9	4.1	3,207	••		1,471	0-0	26	0.0	**	Tension
13	NASA-E	94	Nov	1964	125	P1n _v	20	35	1	4.1	†		••	2,400	940	38	0.0	0.0	Tension
7	E-7			1964	28 28	Plne	2	14	15	4.1	3,392	4,700	1,316	1,780	0-0	26	1.6	0.32	Shear (s Tension
						Pluc	10	26	10	4.1	Ť	44	0.0	2,650	900	38	5.7	0.10	Tension
13	MASA-D	36	Nov	1964	84	Pine	**	28	6	4.2	4,800		40	2,550	360	50	0.0	0-0	Shear (se
13	MASA-A	3	Nov	1964	55	Cypress	8	18	6	4.2	t	44	0-0	820	270	56	0.0	••	Tension (
13		63	Nov	1964	65	Pine	8	20	15	4.2	Ť	**	8-9	3,700	1,500	38	7.0	11	Tension Shear (so Tension
			llov			Pine	50	50	10	4.2	†	0-0	**	2,200	750	38	5.0	0.20	Shear (so Tension (
				1964 1964 - :		Pine Pine	8	21	10	4.3 4.3	7,600	**	0-0	3,175	940	20	0.0	0-0	Shear (se Tension (
7	E-7 4	26 Þ				Pine	3	30	16	4.3	6,800 5,270	6 508	1.060	3,525	1,880	50	0.0	**	Compressi
.3	RASA-A 1	3h 3	lov	1964 1		Pine	25	45	15			6,528	4,962	2,889	0.0	26	1.8	0.28	Elartic (
3				1964 1		Pine	30	35	7	h.3 h.h	t	**	**	3,130	1,380	38	12.2		Shear (so Tension i Shear (so
	E-7 4	35 H	la u	061	71	74								2,100	680	38	0.0	0-0	Tension (
	MASA-C			1964		Pine Pine	20	30	5	4.4	3,952	4,703	3,752	2,655	**	26	1.4		Shear (so Tension (
' 1	MASA-C	11 A	ug 1	964		Pine	12	28	10	4.5	11,277	**	**	4,633	**	26	0.0		Compressi
.3 1	MASA-C	54 H	ov 1	964 (56 1	Pine	7	20	9	4.5	4,0(8	**	0.0	2,072	1 200	26 38	0.0		Tension (
3 1	MASA-A	7 11	ov 1	964	39 1	Pine	18	37	10					4,050	1,320	30	10.3		Compressi
										4.6	*		44	2,750	1,050	38	0.0		Shear (so

See description of test areas and test sites.
 Ho measurement made.
 Total work not recorded.
 Instrumentation felled.

Teble Bl Re Tree Overrije Tests Performed in United States and Thailand

_														
Speed	Maximum		*	Ave	rage Cone	Index			USCS Classif		Moias	ture Con	tent 4	
Contact	Longitudinal Acceleration		0- to 6-in.	5- to 12-in.	12- to 18-in.	18- to 24-1n.	24- to 30-in.	0- to 6-in.	6- to	12- to	0- tu	D= 10	12-	to
aph		Mode of Pailure	Layer	Layer	Layer	Layer	Layer	Layer		Layer	Layer		Layer	
wood Tree	s, United Sta	tes												
0.0	**	Elastic (stem)	420	640	650	700	750	ML	CL-ML	CL	22.1	18.2	26.9	
0.0	0.0	Elastic (stem)	505	192	192	585	474	ML	ML	CL	19.2	15.2	16.6	
0.0	**	Elastic (stam)	200	550	300	340	460	ML	CL-ML	CL	22.9	17 9	_8. I	
0.0	0.0	Elastic (stem) Elastic (stem)	89	112	148	241	295	SH	SP-SM	SP-SP:	7.7	7.1	7.4	4
1.4	0.0	Elastic (stem)	95	118	192	98 222	334	MCs SM	MIL SIP-SIM	CL SP-SM	3.8	14.8	10.5	
0.0	***	Elastic (stem)	330	720	750	750	750	ML	CL-ML	CL	24.5	18.4	21.1	
1.8	0.1	Elastic (stem)	89	112	148	241	295	SM	SP-SM	SP-SY	7.1	7.1	7.4	
0.0	* *	Tension (stem)	200	260	530	550	560	ML	CL-ML	CL	25.6	21.0	21.4	
1.5	0.08	Elastic (stem) Elastic (stem)	540	330	580	380	520	ML	CL-ML	CL	17.6	15.0	14.9	
1.9	0.09	Elastic (stem)	96 124	108	98 192	95 167	91	SM	SP-SM	SP-SH	3.8	4.4	4.8	
0.0	0.0	Compression (riem)	370	470	198	521	575	SM ML	SIP-SIM	SP-SM CL	7.7 14.9	7.1 15.8	7.4	
0.0	0.0	Elastic (stem)	140	150	240	330	500	ML	CL-ML	CL	31.2	23.6	25.2	
0.0	9.0	Elastic (stem)	161	195	159	132	147	ML	ML	CL	28.3	19.5	21.1	
1.5	0.06	Elastic (stem)	104	107	83	89	106	SM	SP-SM	SP-SM	3.8	$l_{b} \downarrow l$	4.8	
0.0	0.09	Tension (stam)	102	118	139	180	250	SM	SI -SM	SP-SM	7.7	7.1	7.4	
0.0	**	Elastic (stem) Tension (stem)	160	120	130	180	260	MIL	CL-ML	CL	25.5	21 8	20.9	
1.8	0.12	Shear (soil)				370	5 30	ML	CL-NL	CL	23.9	20.2	19.6	
		Tension (root)	124	197	192	167	149	SM	SP-SM	SP-SM	7.7	7 1	7.4	
0.0	0.11	Tension (stem)	98	15/	145	243	297	5M	SP-SM	SP-SM	7.7	7-1	7.4	
0.0	**	Tension (stem) Elastic (stem)	136	174 226	184	261	352	ML.	MIL.	CT	24.0	18.3	19.1	Stem appeared infected 8 in. above ground surface
1.5	0.12	Elastic (stes)	132	199	197	157	1 30 197	ML	NOL SP-SM	SIP-SM	3.8	19.8	4.8	
0.0	**	Tension (stem)	206	241	182	150	175	ML	ML	CL	31.6	19.6	19.6	
0.0	**	Shear (soii)	154	194	214	243	362	ML	ML	CL	33 5	21.0	20.6	
1.7	0.30	Tension (root) Elastic (stem)	101	137	170					SP-SM				
0.0	94	Shear (soil)				229	279	SM	SP-SM		7.7	7.1	7.4	
		Tension (root)	136	140	144	172	281	ME	ML	CL	22.2	20.1	21.0	
0.0	**	Tension (root)	188	303	302	**	**	SC-SM	MZ.	CL	5.4	6.8	6.8	
0.0	**	Shear (soil) Tension (root)	253	376	351	**	0.0	SC-SM	ML	CL	5.4	6.8	6.8	Taproot failed 24 in. below ground surface
0.0	94	Shear (acil)	lsOk	418	341	389	435	ML	ML	CL	18.7	16.1	16.9	Entire aroun was not consectided due to show a
0.0	**	Tension (root) Tension (stem)	165	180	166	510				CL	28.6			Entire crown was not overridden due to short departure lane
0.0	9-0	Tension (stem)	217	290	287	40	376	ML ML	ML ML	CL	15.2	20.0	21.2	Small portion of stem was infected
1.6	0. 32	Shear (soil)	83	90	82	99	116			SIP-SM	3.8	l ₄ , l ₄	4.8	Carry of sees ass TitleGred
5.7	0.10	Tension (root)					114	SP4	SP-SM					
		Tension (root) Shear (soil)	304	380	370	**	**	CL-ML	CL-ML	CL	iv.2	16.2	17.5	
0.0	4-6	Tension (root)	585	42k	544	**	0.0	ML	CL	CL	9.6	8.7	11.1	Taproot failed 18 in, below ground surface
0.0	**	Tension (stem)	80	119	127	**	0.0	MOL	CL-ML	CL	28.4	21.3	21.6	Tree appeared to be infected
7.0	† †	Shear (*oil) Tension (root)	160	196	182			CL-ML	CL-ML	CL	20 2	16.2	17.5	17
5.0		Shear (soil)	236	300	21.2	**	66	M	01 10	CI	17 0	17 3	18 =	
		Tension (root)	ل ال	,,,,	313		34	ML	CL-ML	CL	17.8	11.3	18.7	
0.0		Shear (soil) Tension (root)	176	270	294	44		MI.	ML	CL	11.8	10.6	11.7	Taproot did not rupture
0.0		Compression (stem)	230	250	234	**	**	ML	ML	CL	21.2	15.2	15.6	
1.8		Elastic (stem)	110	109	89	90	89	SM	SP-SM	SP-SM	3.8	$I_{k-1}I_k$	4.€	
12.2		Shear (soil) Tension (root)	290	519	545	0.0	9-9	ML	CL-ML	CL	17.8	17.3	18.7	
0.0	**	Shear (soil) Tension (root)	245	320	297	**	**	ML :	ML	CL	15.0	12.1	13.5	Taproot failed 18 in, below ground surface
1.4	0.29	Thear (soil) Tension (root)	77	101	149	207	247	SM	SP-SM	SF-8M	7.7	7.1	7.4	
0.0			506	365	393	426	461	MIL	MIL.	CL	23.0	49.3	20.2	Complete crown was not overridden due to short departure lane
0.0		Persion (stem)		179						CL		14.3	14.3	The second of th
10.3			256	580	174	**	**	CL-NL	CL-ML	CL	20.2	16.2	17.5	
0.0		Shear (soil) Pension (root)	168	515	26%	9-9	**	ME.	CT-ML	CL	17.8	17.3	18.7	
(Cont	inued)													

(1 of 8 sheets)

B

(Continued)

Test chicle	Site No.	Test No.	Test	Date	Tree	Tree Type Tommon Name	Branch- ing Height ft	Tree Beight ft	Crown Disseter ft	Stem Oinn- eter & in. Above- ground, in-	Worm Required to Fall True, lt-ft	Work Required to Override Tree, 1b-ft	Maximum Tractive Force 1b	Maximum Morisontal Pushtar Force, 1b	Maximum Vartical Pushbar Porce, 1b	Pashter Height Above- ground In-	Speed at Contact aph	Maximum Longitudinal Acceleration	Hode o
																Suftwood		United States	Continue
M113	KASA-A	56	Nov	1964	95	Pine	20	**	10	4.6	•	••		2,450	1,020	38	0.0	**	Teneion
M113	NASA-A	53	Bov	1964	92	Pine	20	35	15	4.6	†	**	**	4,050	1,500	38	6.4	††	Teneion
Mil3	MASA-C	72	Bov	1964	103	Pine	10	20	12	4.6	†	••	••	••	**	36	12.7	••	Elastic
M113	KASA-A	132	Roy	1364	163	P1ne	50	36	10	4.6	†	00	••	3,400	1,160	38	13.3	0.40	Shear (s Tension Shear (s
M113	MASA-A	57	Boy	1964	96	Pine	13	32	15	4.7	†	••	••	5,100	670	38	0.0	••	Tension
M113	MASA-A	12	Nov	1964	88	Pine	25	39	7	4.7	†	••	••	3,290	1,000	36	12.4	0.10	Shear (a Tension Shear (a
M113	NASA-E	82	Nov	1964	113	Pine	12	28	10	4.7	†	••	••	3,100	600	36	4.4	11	Tension
M113	MASA-A	124	Hov	1964	155	Pine	25	33	5	4.8	† 4,816	••	••	2,025	••	36 26	0.0	0.10	Tension Tension
M37	MASA-C	14	Aug	1964	14	Pine	9	23	9			••	••						Shear (s
M113	RASA-A	121	POA	1964	152	Pine	30	39	10	4.8	1		••	4,600	000	36	12.9	0.30	Teneion Shear (s
M113	NASA-E	26	- NCA	1964	83	P1ne	••	27	10	4.9	6,080	••		3,500	850	20	1.0		Teneion Shear (s
M37	E-7	430	Hny	1964	65	Pine	4	27	9	4 3	2,854	3,990	3,390	1,713	**	26	1.5	0.18	Tension
M113	NASP-C	68	Roy	1964	99	Pine	7	30	10	4.9	†	••	**	5,750	2,000	38	11.1	††	Teneion
MIII	NASA-E	81	Nov	196h	112	Pine	20	31	9	4.9	t	••	••	3,300	1,400	38	7.0	**	Shear (s Teneion
M113	NASA-A	119	Nov	1964	150	P1ne	24	40	5	4.9	†	••	••	4,300	1,000	36	13.7	0.50	Shear (s Tension
M37	NASA-D	51	Aug	196h	32	Pine	6	21	10	5.0	11,166	**		3,886	**	26	0.0	••	Tension
H113	NASA-B	10	Nov	1964	48	Pine	••	والها	••	5.0	†	••	**	1,825	910	56	0.0	**	Tension
M113	NASA-E	91	Nov	1964	155	Pine	15	25	12	5.0	•	30	**	2,550	1,500	38	1.0	**	Shear (s Teneion
137	E-7	4 34	May	1964	70	Pine	20	36	11	5.0	1,794	10,405	5,770	3,685	**	26	1.4	0.43	Shear (s Tension
Н 37	E-7	140	Mm.y	1964	76	Pine	24	32	9	5.0	5,077	6,290	3,886	2,386	••	26	2.2	0.37	Shear (s Tension
M113	NASA -A	55	Bov	1964	94	Pine	30	lala	10	5.0	†	••	**	4,100	1,150	38	4.3	0.10	Shear (s Tension
(113	MASA-C	60	Nov	1964	59	Pine	7	27	15	5.0	•	••	••	3,800	550	38	4.9	0.30	Shear (s Tension
M113	MASA-C	7 3	Nov	1964	104	Pine	6	27	12	5.0	•	14	••	3,650	950	39	14.0	**	Shear (s Tension
4113	NASA-E	78	Nov	1964	109	Pine	10	24	9	5.0	•	••	••	••	**	36	14.8	ff	Shear (s Tansion
M113	NASA-E	85	Nov	1964	116	Pine	21	39	А	5.0	•	••		••	**	38	10.3	††	Tension
M113	NASA-A	111	Nov	190-	142	P1 ne	8	37	10	5.0	†	••	••	5,150	5,000	38	6.1	0.20	Elastic Shear (s
d13	MASA-B	17	Hov	1964	١7	Pine	10	36	15	5.1	10,400	••	••	5,375	2,600	50	0.0	**	Tension
u 13	MAGA-E	55	Nov	1964	la.	Pine	8	30],14	5.1	13,440	**	••	4,100	1,400	50	0.0	••	Shear (s
013	MASA -A	136	Nov	1964	167	Pine	15	37	15	5.1	†	**	9-9	4,200	975	38	††	††	Shear (s
(113	MASA-C	70	Nov	1964	101	Pine	15	33	10	5.2	1	••	••	7,050	1,550	3/8	10.6	tt	Shear (s Tension
0113	MASA-C	71	Nov	1964	105	Pine	9	27	13	5.2	•	••	••	4,900	1,600	38	11.1	tt	Shear (s
4113	NASA-C	7h	Nov	1964	105	Pine	21	33	8	5.2	•	**	**	6,400	1,550	38	5.9	††	Shear (
(113	MASA-C	76	Nov	1964	107	Pine	8	55	15	5.2	†	C.	••	5,100	1,100	38	8.1	tt	Shear (
0.13	NASA-C	77	Nov	1964	106	Pine	6.7	39	15	5.2	t	••	••	**	++	38	8.1	**	Tension
4113	MASA-A	140	Nov	1964	17.	Pine	14	33	10	5.2	•	• 11	••	4,400	1,100) E	4.6	0.25	Shear (s Tension
4113	MASA-A	141	Nov	19%	172	Pine	24	39	8	5	•	••	**	4,800	1,300	38	7.2	0.40	Shear (s
437	NASA-C	l _b	Au;	1964	ž ₆	Pine	0.5	37	10	5.3	22, kur	••	••	4,256	••	26	0.0	••	Tension
437	NASA-0	23	3	1964	28	Pine	6	22	10	5-3	5,401	••	••	2,887	••	26	0.0	••	Shear (Tension
(113	MASA-B	18	Nov	باراؤء	77	Fine	105	30	+ 5	5 - 3	7,760	••	**	4,550	1,050	20	0.0	••	Shear (: Tension
1113	KASA-E	86	Nov	1964	117	Pine	10	36	15	5.3	†	••	**	4,200	2,300	38	0.0	••	Elastic



Ho measurement made:
† Total work not recorded:
†† Instrumentation failed:

ble Bl (Continued)

Maximum Longitudinal		A .	Ave	rage Con	Index			Classif		Mois	ture Co	mtent, \$	
Acceleration		0- to 6-in.	6- to 12-in.	12- to 18-in.	16- to 24-in-	24 - to 30-in	0- tr	b- to		0- to	6- to	12- t 18-in	
4	Mode of Pailure	Layer		Layer	Layer	Layer				Layer			
ted States													
11	Tension (stem)	268	401	381	••	••	HL	CL-ML	CL	17.6	47.3	18.7	
**	Tension (stem) Elastic (stem)	188	273 324	315	**	••	HL.	CL-HL	CL	17.8	17.3	18.7	
0.40	Shear (soil)			344		••	CL-ML	CL-HL	CL	20.2	16.2	17.5	
	Tension (root)	350	563	5 5 h	**	••	HE.	CL-HL	CL	17.8	17.3	18.7	•
••	Shear (soil) Tension (root)	136	550	270	**	**	M	CL-ML	CL	17.8	17.3	18.7	
0.10	Shear (soil) Tension (root)	280	3 35	282	••	**	ML	CL-ML	CL	17.8	17 3	.0 -	• January and the supplier of
11	Shear (soil)	204	275	2/0	••		170			11.0	17.3	10.7	Taproot failed 12 in. above ground surface
0.16	Tension (root) Tension (stem)			269		••	ML	MIL	CL	15.0	12.1	13.5	
**	Tension (stem)	269 151	383 155	144	217	420	ME.	CL-ML ML	CL	17.8	17.3	18.7	
0.30	Shear (soil)	366	498	497	••	••	ML		CL	31.5	20.7	22.0	
	Tension (root) Shear (soil)						PL.	CL-ML	CL	17.8	17.3	18.7	
••	Tension (root)	247	263	184	**	**	ML	ML	CL	21.2	15.2	15.6	inferted area observed on stem just above ground surface. Taproot failed 12 in. below ground surface
0.18	Shear (soil) Teasion (root)	119	153	107	186	81	884	SP-SM	SP-SM	3.8	4, 4,	4.8	reserve as an octom ground suriece
**	Shear (soil)	228	259	338	••	••	CL-ML	CL-ML					
	Tension (root) Shear (soil)						- TIL	U SAME	T	20.2	16.2	17.5	
.,	Tearion (root)	195	311	394	**	••	ML	ML	CL	15.0	12.1	13.5	
	Shear (soil) Tension (rout)	285	341	294	**	••	ML	CL-ML	CL	17.8	17.3	18.7	
••	Tension (stem)	210	220	200	260	390	ML	CL-ML	CL	13.7	12.9	14.2	
	Shear (soil) Tension (root)	270	119	325	••	••	SC-SM	ML.	CL	5.4	6.8	6.8	
••	Shear (soil)	178	291	286	••	••	M2	Let		,	•.0	0.0	
	Tension (root) Shear (soil)						MI.	MI.	CL	15.0	12.1	13.5	Taproot sailed 6 in. below ground surface
0.4)	Tension (root)	77	101	149	207	247	314	SP-SM	SP+SM	7.7	7.1	7.4	
	Shear (soil) Tension (root)	91	124	137	203	273	э	SP-SM	SP-SM	7.7	7.1	7.4	
	Shear (soil)	331	671	459	**	**	ML	CL-ML					
	Tanalon (root) Shear (soil)								CL	17.8	17.3	18.7	
	Tension (rout)	396	488	422	••	••	CL-ML	CL-ML	CL	20.2	16.2	17.5	Taproot failed 10 in. below ground surface
	Shear (soil) Pension (root)	337	317	407	**	**	CL-ML (CL-ML	CL	20.2	16.2	17.5	
	Chear (soil) Tension (root)	517	750	750	••	••	MT :	Œ.	CL	15.0			
	Tension (stem)	185	250	359	••	**				15.0	12.1	13.5	
C. 20 E	Distic (stem)	533	750		••				CL CL	17.8	17.3	13.5	
	henr (soil) ension (root)	305	361	351	••	••	3C-SM)	00	C.L	13.2	11 0	11.7	<u>.</u>
3	hear (soil)	183	246	274	••			47					
7	hear (soil)						MC N	Œ	CL	14.1	12.1	12.8	Taproot failed 18 ir. below ground surface
T	ension (root)	351	530	590	• •	••	AT. (L-MI.	CL	47.8	17.3	18.7 7	Free failed 22 ft above groun! surface
	hear (soll) ension (root)	184	186	264	••	••	"'-ML 0	LaML	CL	20.2	16.2	17.5	
11 5	hear (soil)	195 2	214	251			CL-ML C	`					
	hear (antl)								TL .	20.2	16	17.5	
To	(1000)	217	3 33	394 .	•	••	L-ML C	L-ML (CL	20.2	16	17.5	
	heer (soil) ension (root)	170 2	217	551	••	• (I-ML C	L-ML (CL.	£3.2	10	17.5	
	hear (soil) ension (root)	520 7	750	750			L-ML C	L_MI					
0.25	hear (soil)								:L	15 0	10.1	13.5	
Te	ension (root)	221 2	297	32A .	•	• •	a c	L-ML C	L	17.*	17.3	10.7	
	hear (soil) ension (moct)	371 5	13	520 •			ц с	L-ML C	L	17	17.3	18.7	
		396 4	13 1	121	>2 4	54 M	EL M						niercarriage of vehicle s rape: bark and wood from tree ster
	mear (soil)	190 2	000	160 8	00 2	80 M	L C	L=H1 C				19.9	or state a raper three und wood from tree stem
•• 3h	mear (soil)	178 2	17	:64 •		• 0							
	me.on (root)			337 •							11.	16.7 T	spront fai in. he.ew ground surfa .
			-/	r 21		• и	L H	, c	T. 1	5.0	2.1	13.5	

(of sheets)



Test Vehicle	Sits No.	Tes.		t•	e S		vor it. ins tight	Tree Helght ft	Or wn Dimmeter ft	tem limmeter - in. A) ve- ground, in.	WOFE FRINGER 'O FRII . Fr., 1 - Ft	ours Required to override Tree, 11-ft	Muximum Tractive For e, ib	Horizontal Pumblar Force, t	Meaimes Vertical Puchtur Fire, b	Pai sr delight stove- dround in.	pec1	Musimum Langitudinal Acceleration	Mode of
																		Suited tates	
M113	A-ALAK	-)	8	v [] »	0	2014	10	40.46	N	5.3	•	••	••	4,750	1.1%	4**	4.0	U. 15	Shear (sci Tension (r
M113	NASA-C	07	3k	V . #	p=	Fin-	+31	4.	A.	5.3	†	••	••	10,700	, 100	\$25	ic.	* *	hear (soi Tension (re
M113	NASA-E	. 50	36.1	V - 10	• .47	Plne		14	1.7	5.4	•	44	**	4,500	1,400	414	J. U	••	hear (sol Tension (re
M113	NASA-A	129	Non	v . g.	4 4 4	Piter		se	10	5.4	†	••	••	4,300	2.500	41-	1 1	0.45	Ten Ion (at
M113	KA.A-A	14.			* * f 1	1 Live		39	10	5.4	•	••	••	3,650	6 %	30	1.3	0.45	Tension (re
M113 M113	NASA-A	1 %	Non			f , at		40	15 15	5 · 5 5 · 5	•	••	••	6,300	5,050	<i>j</i> ."	4.0	0.40	Plastic (at
M113	NASA-A	1 1 1	3	. Ril	.6.	- 1.720	4	15	10	5.5	†	••	**	4,500	250	51	12.7	0.50	Tension (st hear (soil
M213	NASA-A	433	Nev	p :	Le la	Fine		48	10	5.5	t	••	••	5,680	1,100	3€ ¥5	13.1	0.60	Tension (re
н37	E-7	434	Mny	, jen	00	Plne		40	.10	5.6	1,625	15,606	5,154	5,192	••	. 6	1 4	0.50 •0.85	Elastic (st .hear (soil
M37	E-7	late a	May	1.80	77	°lne	100	I _b ()	17	5.5	18,782	23,960	4,447	4,973	••				Tension (ro Thear (soli
M113	NASA-A	116	Sov	1964		Pine	4	444	9						••	26	3. 🤾	•0.85	Tension (ro
										5.6	†	••	**	5,600	1,200	3/1	13.1	0.60	Tension (ro
M113 M37	NASA-E E-7	79 436	Nov			Pine	10	41	10	5.7	*	**	••	**	††	38	0.0	••	Tension (ro
437	E-7	429	May		72	Pine Pine	. 5	40 2H	20	5.7 5.8	**	**	5,251 4,729	**	••	16	1.7	-0.70	No Failure
a 13	NASA+C	75	Nov	1364	106	Pine	8	24	14	5.8	t	**	••	7,300	1,550	40	5.9	-0.70	No Failure Thear (soil
013	NASA-A	117	Nov	1964	149	Pine	30	42	9	5.8	•	••							Tension (ro Thear (soil
137	E-7	428	Mny	1964	63	Pine	5	40	20	5.9	**	††	5,623	**	1,400	38 26	11.4	0.70	Tension (ro
013	NASA-A	120	Nov	1964	151	Pine	18	•-	12	5.9	†	••	**	7,550	1,740	38	17.1	0.30	No Failure Chear (soil
u13	NASA-E	150	Nov	1964	181	Pine	58/	51	d	6.0	22,320	**	••	7,650	3,650	20	0.0	**	Tension (ro Elastic (st
u 13	NASA-E	83	Nov	1964	114	Pine	40	48	15	6.0	t	••	••	tt	tt	38	9.1	††	Chear (soil
113	NASA-A	112	Nov	1964	143	Pine	25	48	12	6.0	t	••	**	8,300	2,100	38	6.1	0.40	Tension (ro
113	NASA-B	15	Nov	1964	12	Plne	15	35	23	6.1	27,920	••	••	10,350	2,9.5	.20	0.0	••	Tension (ro Tension (ro
113	NASA-E	80	Nov	1964	111	Pine	20	42	10	6.1	t	••	••	7,250	2,300	38	12.5	11	Shear (soll Tension (ro
113	MASA-A	115	Nov	1964	146	Pine	24	45	15	6.1	t	**	••	6,800	1,975	38	11.3	0.80	Lhear (soll
113	NASA-E	84	Nov	1964	115	Pine	18	47	7	6.2	t	••	••	9,300	2,600	38	5	**	Tension (ro
113	NASA-A	125	Nov	1964	156	Plne	40	55	15	6.2	•	••	••	6,750	1,650	38	13.5	0.60	Shear (soil Tension (ro
113	NASA-E	90	Nov	1964	121	Pioe	16	35	19	6.3	•	••	••	**	**	38	13-7	**	Shear (soii Tension (ro
113	MASA-B	20	Nov	1964	79	Pine	14	36	11	6.4	16,560	••	**	9,450	2,000	20	0.0	**	Chear (soil)
113	MASA-1	32	Nov	1964	19	Plne	20	45	10	6.4	23,520	••	0-0	13,900	5,800	20	0.0	**	Shear (soil) Tension (ro
113	NASA-1	16.24	Nov	1964	90	Pine	30	50	20	6.4	•	••	**	9,200	2,300	38	5. 2	**	hear (soil)
113	MASA-A	139	Nov	1964	170	Pine	30	54	5	6.5	•	••	••	9,500	2,375	38	6.3	0.70	Tension (roo Chear (soll)
113	MASA-A	145	Nov	1964	174	Pine	24	37	12	6.5	•	••	**	7,600	2,450	36	4.8	0.40	Tension (roo Shear (soil)
113	KASA-D	36	Nov	1964	71	Pine	15	30	12	6.6	23,440	••	••	8,050	4,350	20	0.0		Tension (roo Tension (sta
113	MASA-A	h	Nov	1964	59	Pine	12	45	18	6.6	t	••	**	3,700	1,850	56	0.0	••	Shear (soll) Tension (roo
13	MACA-C	69	Nov	1964	100	Pine	15	27	15	6.6	•	••	••	5,800	1,900	36	0.0	••	Chear (soll) Tension (roc
113	MASA-C	65	Nov	1964	67	Pine	12	33	15	6.6	•	••	••	**	**	38	6.3	••	Shear (soii) Tension (roc
13	Masa-E	104	Nov	1964	1 35	Pine	14	45	20	6.6	*	••	••	10,700	2,300	38	9.0	••	Shear (soil) Tension (ros
13	MASA-R	106	Nov	1964	137	Pine	30	48	10	6.6	•	••	••	9,650	2,000	38	8.4	••	Tension (roo Tension (roo
.13	NASA-E	108	Nov	1964	139	Pine	50	40	10	6.6	t	••	**	9,500	1,950	36	3-7	••	Shear (soil) Teneion (roc
.13	NASA-A	1 37	Nov	1964	168	Pine	20	69	20	6.6	•	••	10	8,800	1,500	38	12.6	0.40	Shear (soil)
-	surement													ericorii.				tinued)	Tenslor (ros

No reasurement made.
 Total work not recorded.
 Instrumentation falled.

Tuble B1 (Continued)

1	Mode of Failure ntinued' hear (soil)	50- to 6-4in. Layer 215 201 118 218 218 219 200 299 360 124 97 234 367 90 102 332 378 117	12-in.		18_ to 24-in. Layer	30-in. Layer	D. To G. In Layer CLMI. MI. MI. MI. MI.	6- to 12-in Layer	18-in.	C+ to	17-3 16-2 12-1 17-3 17-3 17-3 17-3	L- to	Taproot falled 18 in. below ground surface Taproot falled 18 in. below ground surface Stem failed in tension 6 in. above ground surface Taproot falled 18 in. below ground surface. Main stem fail 44 ft above ground surface Tree failed in tension 8 ft above ground surface Main stem failed 25 ft above ground surface
1	netinued' hear (soil) ension (root) hear (soil) ension (root) hear (soil) ension (root) hear (soil) ension (soil) hear (soil) ension (stem) hear (soil)	215 201 118 218 229 360 299 360 124 97 234 367 90 102 332 378	285 239 112 349 368 750 297 477 614 197 135 362 472 120 133	335 261 185 361 316 750 292 572 640 192 160 414	167 205		ME CL-ME ME M	CL-ML	CL CL CL CL CL CL CL CL	17.6 20.2 15.0 17.8 17.8 17.8 17.8	17.3 16.2 12.1 17.3 17.3 17.3 17.3	18.7 17.5 13.5 16.7 16.7 16.7 16.7	Taproot falled 18 in, below ground surface Taproot falled at ground surface Stem falled in tension 6 in, above ground surface Taproot falled 18 in, below ground surface. Main stem fail A ft above ground surface Tree failed in tension 8 ft above ground surface
0.35 Shear Tens 11 Shear Tens 12 Shear Tens 13 Shear Tens 14 Shear Tens 15 Shear Tens 16 Shear Tens 17 Shear Tens 18 Shear Tens	near (soii) ension (root) ension (root) ension (root) ension (root) ension (root) ension (root) ension (soii) ension (stem) ension (stem) ension (stem) ension (stem) ension (stem) ension (root)	201 118 218 236 519 200 299 360 124 97 234 367 90 102 332	239 112 349 468 750 477 614 197 135 362 472 120 133	261 185 361 316 750 292 572 640 192 160 414			CL=ML ML M	CL-NL CL-ML CL-ML CL-ML CL-ML CL-ML CL-ML CL-ML SP-DM	CT CT CT CT CT CT	20.2 15.0 17.8 17.8 17.8 17.8	16.2 12.1 17.3 17.3 17.3 17.3	17.5 13.5 16.7 16.7 16.7 16.7	Thereof falled at ground surface Stem failed in tension 6 in, above ground surface Temproof falled 18 in, below ground surface. Main stem failed in tension 8 ft above ground surface. Tree failed in tension 8 ft above ground surface.
11	ension (root) ener (soil) ener (soil) ener (soil) ener (soil) ener (soil) ener (soil) ension (root) ener (soil)	201 118 218 236 519 200 299 360 124 97 234 367 90 102 332	239 112 349 468 750 477 614 197 135 362 472 120 133	261 185 361 316 750 292 572 640 192 160 414			CL=ML ML M	CL-NL CL-ML CL-ML CL-ML CL-ML CL-ML CL-ML CL-ML SP-DM	CT CT CT CT CT CT	20.2 15.0 17.8 17.8 17.8 17.8	16.2 12.1 17.3 17.3 17.3 17.3	17.5 13.5 16.7 16.7 16.7 16.7	Thereof falled at ground surface Stem failed in tension 6 in, above ground surface Temproof falled 18 in, below ground surface. Main stem failed in tension 8 ft above ground surface. Tree failed in tension 8 ft above ground surface.
Term She Term 0.45 Term 0.45 Term 0.40 Ela 0.50 Term 11 Term 0.50 Eln -0.85 Term -0.85 Term -0.85 Term -0.85 Term -0.85 Term -0.85 Term -0.86 Term -0.70 Ho I 11 Term 0.70 Term -1.14 No F 6.90 Sheat Term 11 Sheat Term 0.40 Sheat Term 0.40 Sheat Term 0.80 Sheat Terms 0.80 Sheat 11 Elas: 0.60 Sheat 11 Sheat Terms 11 Sheat Terms 12 Sheat Terms 13 Sheat Terms 14 Sheat Terms 15 Sheat Terms 16 Sheat Terms 17 Sheat Terms 18 Sheat Terms 19 Sheat Terms 10 Sheat Terms 11 Sheat Terms 12 Sheat Terms 13 Sheat Terms 14 Sheat Terms 15 Sheat Terms 16 Sheat Terms 17 Sheat Terms 18 Sheat Terms 19 Sheat Terms 10 Sheat Terms 11 Sheat Terms	ension (root) ear (soil) minsion (root) minsion (root) minsion (stem) ear (soil) main (stem) ear (soil) main (root) Failure Failure fair (soil) main (root) Failure fair (soil) main (root) Failure fair (soil) main (root) Failure fair (soil)	218 236 519 200 299 360 124 97 234 367 90 102 332 378	112 349 368 750 297 477 614 197 135 362 472 120 133	185 361 316 750 292 572 640 192 160 414			ME ME ME ME ME ME ME ME ME ME ME	ML CL=ML CL=ML CL=ML CL=ML CL=ML CL=ML CL=ML	CT CT CT CT CT	15.0 17.8 17.8 17.8 17.8 17.8	12.1 17.3 17.3 17.3 17.3 17.3	13.5 16.7 16.7 16.7 16.7 16.7	Stem failed in tension 6 in, mbove ground surface Taproot falled 18 in, below ground surface. Main stem fail 24 ft above ground surface Tree failed in tension 8 ft above ground surface
Ter Color	ension (root) ension (stem) eser (soil) ension (root) eser (soil)	218 236 519 200 299 360 124 97 234 367 90 102 332	349 368 750 297 477 614 197 135 362 472 120 133	361 316 750 292 572 640 132 160 414		** ** ** ** 149	ME.	CL-ML CL-ML CL-ML CL-ML CL-ML CL-ML	CT CT CT CT	17.8 17.8 17.8 17.8 17.8	17.3 17.3 17.3 17.3 17.3	16.7 16.7 16.7 16.7 16.7	Stem failed in tension 6 in, above ground surface Taproot falled 18 in, below ground surface. Main stem fail 24 ft above ground surface Tree failed in tension 8 ft above ground surface
0.45 The Ten 0.40 Ela 0.50 Ten 11 Ten 0.50 Eln 12 Ten 13 Ten 14 Ten 15 Ten 16 Ten 17 Ten 18 Ten 18 Ten 19 Ten 19 Ten 19 Ten 10 Ten 11 Ten 11 Ten 11 Ten 12 Ten 13 Ten 14 Ten 15 Ten 16 Ten 17 Ten 18 Ten 18 Ten 19 Ten 19 Ten 10 Ten 10 Ten 11 Ten 11 Ten 11 Ten 12 Ten 13 Ten 14 Ten 15 Ten 16 Ten 17 Ten 18 Ten 18 Ten 19 Ten 19 Ten 19 Ten 19 Ten 19 Ten 10 Ten 10 Ten 11 Ten 11 Ten 12 Ten 13 Ten 14 Ten 15 Ten 16 Ten 17 Ten 17 Ten 18 Ten 18 Ten 19 Ten	pear (soil) maion (root) mastic (stem) maion (stem) mer (stem) maion (root) mastic (stem) matic (stem) matic (stem) matic (stem) matic (stem) matic (stem) maion (root) matic (stem) maion (root) matic (stem) maion (root) mar (soil) maion (root) mar (soil) maion (root) Failure Failure mar (soil) maion (root) Failure mar (soil) maion (root) Failure mar (soil)	236 519 200 299 360 124 97 234 367 90 102 332	168 1750 297 477 614 197 135 362 472 120 133	316 750 292 572 640 192 160 414	 167 205	149	ME M	CL-ML CL-ML CL-ML CL-ML CL-ML SP-DM	CT CT CT CT	17.8 17.8 17.8 17.8	17.3 17.3 17.3 17.3	16.7 18.7 18.7	Taproof falled .8 in, below ground surface. Main stem fall 24 ft above ground surface. Tree failed in tension 8 ft above ground surface
0.40 Elas 0.50 Ten 11 Che 12 Che 13 Che 14 Che 15 Che 16 Che 16 Che 17 Che 18 C	matic (root) matic (stem) matic (root) matic (stem) matic (stem) matic (stem) matic (soil)	519 200 299 360 124 97 234 367 90 102 332 378	750 -97 477 -14 197 135 362 472 120 133	750 292 572 640 192 160 414	 167 205	149 293	ME ME ME JM	CL-ML CL-ML CL-ML CL-ML SP-SM	CL CL CL	17.8 17.8 17.8	17.3 17.3 17.3	18.7 18.7 18.7	The failed in tension θ ft above ground surface
0.50 Ten 11 Che Ten 0.50 Eln 10.65 Shea -0.65 Shea 11 Che Ten 0.60 Shea 11 Shea	ear (soin) ear (soin) melon (root) matic (stem) ear (soil) matic (stem) ear (soil) matic (root) ear (soil) ear (soil) ear (soil) ear (soil)	200 299 360 124 97 234 367 90 102 332 378	297 477 614 197 135 362 472 120 133	292 572 640 192 160 414 517	167 205	 149 293	ME. ME. SM	CL-ML CL-ML CL-ML SP-SM	CL CL	17.8 17.8 17.8	17.3 17.3 17.3	18.7 18.7	
11 Che Ten 0.50 Eln Ten 0.65 The Ten 0.60 Sheat Ten 0.60 Sheat Ten 0.70 Sheat Ten 0.70 Chea Ten 11 No F C.90 Chea Ten 12 Sheat Ten 0.40 Sheat Ten 0.40 Sheat Ten 0.80 Sheat Ten 11 Elas 11 Elas 11 Sheat Ten 11 Sheat Ten 12 Sheat Ten 13 Sheat Ten 14 Sheat Ten 15 Sheat Ten 16 Sheat Ten 17 Sheat Ten 18 Sheat	ear (soil) nelon (root) natic (stem) ear (soil) natic (stem) ear (soil) nation (root) ear (soil) nation (root) ear (soil) nation (root) ear (soil) nation (root) Failure Failure ear (soil) nation (root) Failure fail (soil) nation (root) Failure ear (soil)	299 360 124 97 234 367 90 102 332	477 614 197 135 362 472 120 133	572 640 192 160 414 517	 167 205	149 293	ME ME SM SM	CL-ML CL-ML SP-JM	CL	17.8 17.8	17.3	16.7	
0.50 Eln -0.65 The -0.65 The -0.65 The -0.60 Eln -0.60 Eln -0.70 Ro I -0.70 Ro I -0.70 Eln -1.14 No F -1.14 No F -1.14 Shea -1.15 Shea -1.15 Shea -1.16 Shea -1.17 Shea -1.17 Shea -1.18 Shea	nstic (stem) ear (soil) nsion (root) Failure Failure ear (soil) nsion (root) Failure for (soil) Failure for (soil) Failure for (soil)	360 124 97 234 367 90 102 332	197 135 362 472 120 133	640 192 160 414 517	167 205	149 293	ML MC MC	CL-ML SP+JM	CL	17.8	17.3		Main stem failed 35 ft above ground surface
-0.85 Shear -0.85 Ten -0.85 Ten -0.86 Shear -0.70 Shear -0.70 Shear -0.70 Shear -1.14 No F -1.14 No F -1.15 Shear -1.16 Shear -1.16 Shear -1.17 Shear -1.18 Shear -1.1	ear (soil) naion (root) ear (aoil) naion (root) ear (aoil) naion (root) ear (aoil) naion (root) Failure Failure far (soil) naion (root) Failure far (soil) naion (root) Failure far (soil) far (soil) failure far (soil)	97 234 367 90 102 332 378	197 135 362 472 120 133	192 160 414 517	167 205	149 293	3M 3M	SP-JM				19.7	0
-0.85 Shear -1.14 No. F Elas -1.15 Shear -1.16 Shear -1.17 Shear -1.18 Shear	ear (soil) maion (root) ear (soil) malon (root) ear (soil) malon (root) Failure Failure ear (soil) maion (root) Failure Fair (soil) maion (root) Failure ear (soil)	97 234 367 90 102 332 378	135 362 472 120 133	160 414 517	205	293	ЭМ		SP-3M	3.8	1		
Ten Ten	naion (root) mar (aoil) mar (aoil) malon (root) mar (aoil) malon (root) Failure Failure mar (aoil) maion (root) mar (aoil) maion (root) Failure mar (aoil)	234 367 90 102 332 378	362 472 120 133	517	••			SP-SM			la . la	4.8	
Ten.	nalon (root) ear (acil) nalon (root) Failure Failure tar (acil) nalon (root) sar (acil) sar (acil) sar (acil) sar (acil) sar (acil) sar (acil)	367 90 102 332 378	120 133	517		••	MIT		SP-IM	7.7	7.1	7.4	
-0.90 No I -0.70 No I -1.14 No F -1.14 No F -1.14 No F -1.690 Shea -1.60 Shea -1.60 Shea -1.70 Shea	railure Failure	90 102 332 378	120		**		ML	CL_ML	CL	17.8	17.3	18.7	
-0.70 80 1 11 Sheet 12 Sheet 11 Sheet 11 Sheet 12 Sheet 12 Sheet 13 Sheet 14 Sheet 15 Sheet 16 Sheet 17 Sheet 17 Sheet 18 Sheet 19 Sheet	Failure Par (soil) Usion (root) Par (soil) Usion (root) Failure Par (soil)	332 378	133	150		**	ML	MIL	CL	15.0	12.1	13.5	Portion of stem was infected from the ground surface to a height of 4 in.
11 Shear 0.70 Chea 1.14 No F 0.90 Chea 1.15 Chea 11 Chea 12 Chea 12 Chea 13 Chea 14 Chea 15 Chea 16 Chea 17 Chea 18 Chea 18 Chea 18 Chea 19 Chea 19 Chea 19 Chea 19 Chea 19 Chea 10 Chea 11 Chea 11 Chea 11 Chea 12 Chea 13 Chea 14 Chea 15 Chea 16 Chea 17 Chea 18 Ch	ear (soil) maion (root) ear (soil) maion (root) Failure ear (soil)	332 378		1 - 4	237	298	OM.	SP-SM	SP+FM	7.7	7.1	7.4	Vehicle Immobilized
7en: 0.70 Shear 1.14 No F 0.90 Shear 11 Shear 11 Shear 12 Shear 14 Shear 15 Shear 16 Shear 17 Shear 18 Shear 19 Shear 19 Shear 11 Elas: 11 Shear 11 Shear 11 Shear 11 Shear	ear (soil) sion (root) Failure ar (soil)	378	519	139	115	113	3H	SP-JM	SP-3M	3.8	4.4	7.8	Vehicle immobilized
-1.14 No F 0.90 Shea Tens t Shea Tens O.40 Shea Tens Shea Tens t Shea Tens O.80 Shea tt Elas O.60 Shea Tens t Shea Tens	Failure ar (soil)		Lou	480	••	••	CL-ML	CL-ML	CL	20.2	16.2	17.5	Inferted taproot. Taproot failed 10 ln. below ground surfa
0.90 Shea Tenn the Shea Tenn 0.40 Shea Tenn the Shea Tenn 0.80 Shea Tenn the Elast 0.60 Shean the Shean	ar (soil)		491	441	**	••	ML	CL-ML	CL	17.8	17-3	18.7	
## Elas ## Elas ## Elas ## Shea ## Shea ## Shea ## Elas ## Elas ## Shea ## Shea ## Shea ## Shea	sion (root)		132	106	85	67	SM	SP-JM	SP-JM	3.8	4,4	4.9	Vehicle immobilized
11 Sheal		327	370	314	••	••	ML	CL-ML	CL	17.8	17.3	18.7	Stem was snapped off at the pushbar height of 38 in. and fe on top of the vehicle
71 Tens 0.40 Shea	stic (stem) ar (soil)	396	527	5 34	••	**	ML	ML	CL	15.0	12.1	13.5	
Tens tt Shea Tens 0.80 Shea tt Elast 0.60 Sheaa Tens tt Sheas Sheas Tens tt Sheas	sion (ruot) ar (soil)	307	362	275	**		MIL	MC	CL	15.0	12.1	13.5	
Tens 11 Shea. Tens 0.80 Shea: Tens 11 Elas: 0.60 Shea: Tens 11 Elas:	sion (root)	265	h 37	552	••	••	ML	CL-ML	CL	17.8	17.3	18.7	
Tens 0.80 Shear Tens 11 Elast 0.60 Shear Tens 11 Shear	er (soil) sion (root)	183	256	259	••	••	SC-SM	ML	CL	13.8	13.1	13.9	Undercarriage of vehicle iraggei on the exposed root bulb
Tens: tt Elas: 0.60 Shenz Tens tt Shenz	er (soil) sion (root)	265	359	384	••	••	MZ.	ML	CL	15.0	12.1	13.5	
0.60 Shena Tens Shena	ar (soil) sion (root)	508	*50	750	••	••	ML	CL-ML	CL	17.8	17.3	18.7	
Tens Shess	stic (stem)	101	474	545	••	••	MC	MIL	CL	15.0	12.1	13.5	
	ur (soil) Flon (root)	349	596	645	**	••	ME.	CL-ML	CL	17.8	17.3	13.9	Taproot failed 18 in, below ground surface
201102	ur (soil) ion (root)	212	291	345	**	••	Œ.	ML	CL	15.0	12.1	13.5	Taproot failed 18 in. below ground surface. Stem assumed a bow shape immediately after contact
	ar (soil) sion (rout)	293	310	340	••	••	3C-SM	ML	CL	10.6	9.5	12.4	Tuproot failed 30 in, below ground surface
	r (soil) ion (root)	246	326	319	••	•• ,	1	CL	CL	18.6	15.3	14.8	Taproot falled 64 in. below ground surface
	r (soil) ion (root)	335	415	333	••	. 5	Œ.	Li_ML	CL	17.8	17. 3		Taprost falled in, below ground surface
	r (soil) ion (root)	386	502	464 e	9-0	٠. ه	a.	CL-ML	CL	17 ^R	17.3		Daproot failed 5 in. he ow ground surface
	r (soil) ion (root)	214	≥57	253	••	** y	ı.	CL-ML	CL	17.8	17.3		Paproot falled if in, below ground surface
** Tensl	lon (stem)	294	493	492	••	,	D	CL	CL	15.5	12.7		Stem fell against a neighboring tree before contacting
se Shear Tensi	r (soil) ion (root)	327	374	423	••	** y	a (CL-ML	CL	12.9	20.1	ec.7	the ground
	r (soii) lon (root)	190	236	316 •		•• 0	L-ML (L-ML	CL	20.2	16.2	17.5	
	r (soii) ioa (root)	205	315	376 •	•	•• c	L-ML (L-ML	CL	0.2	16.	17.	
	r (soil) lon (root)	183	279	305	•	•• н	L)	Œ.	CL	15.0	10.1	13.5 1	approot failed 30 in. Welow ground surface
	r (soil) ion (root)	236	374	531 +		•• н	L »	Œ.	CL	15.0	12.1		ree crown failed 28 ft above ground surface
	(soil)	136 8	222	311 **	•	•• N	L .	rL (CI.	15.0	L2.1		aproot failed 36 in, below ground surface
0.60 Shear Tensio	lon (root)	326 6	576	682 •		•• ж		L-ML	CL	17.8			tem failed in tension 6 ft above ground surface

(3 of A heets)



Table Bl (Continued)

Test Vehicle	Site No.	Test No.	Test	1 Date	Tree No.	Tree Type 'omnor Name'	Branch- lng Height ft	Tree Helght ft	Crown Diameter	Diameter 42 in. Above- ground, in.	Work Required to Fall Tree, 15-ft	Work Hequired to Overrise Tree, 1b-ft	Haximum Tractive Force, 1b	Maximum Horizontal Pushbar Forcs, 1b	Maximum Vertical Punhbar Porce, 11	Pushbar Height Above- ground ln.	Speed at Contact uph		Mode
M113	NASA-D	37	Nov	1964	70	Plne	20	4.	10	6.7	11	••		**	**	Softwood			(Continu
N113	NASA-E	107	Nov	1964	135	Pine	15	45	20	6.7	†	**	**		††	.0	0.0	••	Tensio
												••		8,550	2,700	BE	4.7	**	Tensio
N113	RASA-A	122	Nov	1964	153	Pine	25	47	15	6.7	†		••	8,000	2,300	38	8.7	1.00	Tenslo
N113	NASA-E	88	Nov	1904	119	Plne	15	32	25	6.8	t	••	**	††	tt	38	14.2	† †	Tens io
M113	MASA-1	118	Nov	196h	148	Pine	24	58	12	6.8	t	••	**	9,450	2,550	38	5.7	1.10	Tensio
H113	NASA-E	146	NOA	1964	177	Pine	30	46	15	6.9	20,960	••	**	8,800	1,975	50	0.0	**	Shear Tensio
M113	NASA-A	46	Nov	1964	40	Pine	30	50	15	6.9	†	**	**	8,050	2,400	38	0.0	**	Shear Tensio
M113	NASA=C	66	Nov	1964	72	Pine	7	33	17	6.9	†	••	••	6,100	3,250	38	0.0	+0	Shear Tensio
N113	NASA-E	102	Nov	1964	133	Pine	15	42	25	6.9	†	**	•	15,200	3,300	38	8.5	**	Shear Tensio
ж113	NASA-A	135	Nov	1954	166	Pine	50	45	20	6.9	•	••	••	8,100	2,600	38	12.8	0.90	Shear Tensio
M113	NASA-A	143	Nov	1964	175	Pine	24	45	12	6.9	t	**	**	7,800	2,000	38	11.9	0.50	Shear Tensio
M113	NASA-E	28	Nov	1764	1	Pine	15	32	18	7.0	22,560	**	**	12,000	2,700	20	0.0	**	Shear Tensio
M113	NASA-C	62	Nov	1964	63	Pine	13	30	15	7.0	•	••	**	10,700	2,700	38	4 7	0.40	Shear Tensio
M113	NASA-E	92	Nov	1964	123	Pine	35	45	14	7.0	•	••	**	18,400	3,700	38	14.0	††	Shear Tensio
K11 3	HASA-E	95	Nov	1964	12t	Pine	15	46	20	7.0	•	••	••	11	**	36	10.6	**	Shear Tensio
M113	NASA-E	103	Nov	1964	134	Pine	15	43	25	7.0	•	••	••	15,550	2,850	38	12.7	**	Shear Tensio
M113	NASA-A	110	Nov	1964	141	Pine	24	52	15	7.0	t	••	**	10,800	tt	33	14.6	0.75	Shear
N113	NASA-E	23	Nov	1964	80	Pine		67	51	7.1	40,320	••	**	15,300	3,800	9	0.0	**	Tension Shear
M113	NASA-E	147	Nov	1964	178	Pine	25	40	12	7.1	22,560	••	**	12,200	1,780	20	0.0	••	Tension
м113	NASA-D	35	Nov	1964	25	Pine	15	42	20	7.2	21,600	**	**	9,940	2,275	20	0.0	**	Tensio Shear
10.13	NASA-D	30	Nov	1964	17	Pine	20	50	25	7.3	33,400	••	••	15,600	5,800	20	0.0	0.01	Tension Tension
N113	MASA-A	48	Nov	1964	38	Pine	30	48	20	7 - 3	+	••	**	9,600	2,100	38	0.0	••	Shear Tension
M11 3	MASA-E	96	Nov	1964	127	Pine	30	40	13	7.4	•	••	••	9,500	2,400	38	0.0	••	Shear Tension
N113	MASA-E	99	Nov	1964	130	Pine	18	38	50	7.4	•	••	**	**	**	38	0.0	••	Tension
M113	MASA-E	157	Nov	1964	188	Pine	24	55	12	7.4	•	••	**	7,300	1,525	38	0.0	••	Shear Tension
M11 3	NASA-B	13	Nov	1964	40	Pine	40	57	15	7.5	•	**	••	7,600	2,100	56	0.0	••	Shear Tension
M113	MASA-E	97	Nov	1965	126	Pine	20	4,7	25	7-5	1	••	**	19,900	4,500	38	10.3	11	Shear Tension
M113	RASA-A	128	Nov	1965	158	Pine	Oc	60	10	7.5	•	••	**	13,100	1,100	38	13.1	1.25	Shear Tension
M13	MASA-D	31	Nov	1964	18	Pine	18	45	20	7.6	36,320	44	**	14,100	3,750	20	0.0	**	Shear Tension
M113	NASA-E	∡+d	Nov	1964	19	Pine	32	51	16	7.6	36,560	••	••	17,550	2,000	20	0.0	0.25	Shear
м13	NASA-E	87	Nov	1964	118	Pine	16	45	35	7.6	•	**		**	**	38	5.8	ŧŧ	Shear Tension
m 13	X-APAK	105	Nov	1964	136	Pine	50	45	25	7.6	•	**	••	11,200	2,800	38	7 - 7	11	Shear
M113	MASA-A	113	Nov	1964	144	Pine	30	60	18	7.6	1		••	12,200	2,150	38	5.7	0.80	Shear
113	HASA-E	89	26 V	1964	120	Pine	15	32	25	7.6	-	**	**	11	11	38	8.5	11	Tension
C13	MASA-A			1964		Pine	38	51	16	7.6	10	••	**	13,000	4,300°	38	15.0	1.20	Tension Shear
				1964		Pine	35	48	30	7.7	1	**	**	13,700	3,200	38	11.2	11	Tension Shear
				1964		Pine	20	52	20				•						Tension Shear
										7.8	•			16,100	4,200	38	12.2	***	Tension
	MARKET STATE	• 6 [Nov	1964	154	Pine	25	57	15	7.8	•	**	**	17,150	-1,950	雅	10.8	(Continued)	Tension

No measurement made.
 Total work not recorded.
 Instrumentation failed.



Table 21 (Continued

ed	Meximum			Ave	erage Cons	Index		Set	Classi	fication	h44		-	
act	Longitudinal Acceleration		0- to	0 6- to	12- to 18-in.	15- 10	24. to	0- tc	6- to	12- to	0= £0	6- to	ntent, g	0
<u>b</u>		Mode of Pailure	Laysı	Layer	Layer	Layer	30-in. Layer	6-in.			6-in.	12-in	. 18-in	•
8, 1	Inited States	(Continued)				100	200					-7-1	- Sayer	Remarks
0	••	Shear (soii) Tension (root)	≥86	146	569	**	**	HL.	CL	CL.	9.6	8.7	11.1	Taproot failed 30 in. below ground surface
7	* *	Shear (soil) Ten:100 (root)	128	1 35	210	••	••	ML	ML	CL	15.0	12-1	13.5	
7	1.00	Shear (soii) Tension (root)	297	403	353	••	**	ML	CL-ML	CL	17.8	17.3	18.7	
	**	Shear (soil) Tension (root)	218	366	451	**	••	ML	ML	CL	15.0	12.1	13.5	
	1.10	Shear (soil) Tension (root)	354	507	495	•-5	••	ML	CL-ML	CL	17.6	17.3	18.7	
	**	Shear (soil) Tension (root)	301	341	298	**	**	ML	ML	CL	15.0	12.1	13.5	Teproot feiled 36 in. below ground surface
	**	Shear (soil) Tension (root)	181	313	393	**	**	ML	CL-ML	CL	17.8	17. 5	18.7	9.000
	••	Shear (soil) Tension (root)	306	350	310	**	**	CL-ML	CLAYL	CL	20.2	16.2	17.5	Taproot failed 12 in. below ground surface
	**	Shear (soil) Tension (root)	197	232	260	••	••	ML	ML	CL	15.0	12.1	13.5	Storing surject
	0.90	Shear (soil) Tension (root)	461	660	651	**	••	ML	CL-ML	CL	17.8	17.3	18.7	
	0.50	Shear (soil) Tension (root)	261	364	372	••	••	ML	CL-ML	CL	17.8	17.3	18.7	Tsproot failed 30 in, below ground surface. Main stem fail
	••	Shear (soil) Tension (root)	277	358	280	••	**	ML	ML	CL	13.5	11.4	14.1	36 ft above ground surface Taproot failed 36 in. below ground surface
	0.40	Shear (soil) Tension (root)	181	181	233	••	••	CL_ML	CL-ML	CL	20.3	16.2	17.5	Taproot failed 24 in, balow ground surface
	**	Shear (soil) Tension (root)	213	314	376	••	**	ML	ML	CL	15.0	12.1	13.5	
	**	Shear (soil) Tension (root)	193	269	237	••	••	MZ	ML	CL	15.C	12.1	13.5	Tappoot failed 12 in, balow ground surface
	††	Shear (soil) Tension (root)	194	254	544	**	•• ;	MZ.	ML	₹.	15.0	12.1	13.5	Taproot failed 48 in, below ground surface Taproot failed 24 in, below ground surface, Main stem fail
	0.75	Shear (soil) Tension (root)	517	750	750	••				CL	17.8	17.3	18.7	32 ft above ground surface Stem was anapped off at the pushbar height of 38 in. and fa
	**	Shear (soil) Tension (root)	241	355	435	••	•• ,			CL	14.0	11.4	10.2	on 25 of venicle
	**	Shear (soil) Tension (root)	234	359	454	••				CL	15.0	12.1	13.5	Taproot felled 24 in. below ground surface
	••	Shear (soil) Tension (root)	125	151	236	**				-	12.5	10.7		Taproot failed 24 in, below ground surface
	0.01	Tension (stem)	329	553	598	••					18.6	15.3	13.7	Taproot failed 24 in. below ground surface
		Shear (soil) Tension (root)	220	326	380	••	•• ×	E (CL-ML		17.8	17.3	18.7	Taproot failed 36 in. balow ground surface
		Shear (soil) Mension (root)	186	323	390	••	•• н	L)	g.	CL	15.0	12.1	13.5	Proot of tracks raised about 6 in. off the ground
		Pension (stam) Thear (soil)	225	261	263	••	•• н	L)	a.	CL	15.0	12.1		A portion of the main stam was infected
	7	ension (root)	166	172	300	••	•• и	L p	a .	CL	15.0	12.1		Taproot failed 12 in. below ground surface
	1	hear (soil)	221	365	456	••	9	C-SM N	at (CL	6.8	6.1	7.9	
	τ.	hear (soil) ension (root)	330	516	580	•• •	• м	L N	Œ (CL .	15.0	12.1	13.5	Taproot failed 48 in. below ground surface
	T	ension (root)	291	380	424	• •	•• м		L-ML (n.		17.3		Tree Sailed at pushbar height and fell on top of vehicle
	Т	ension (FOOt)	213	215	500	• •	• м	c	L c	L I	8.6	15.3		Tsproot failed 12 in, below ground surface
	T.	ension (Fode)	196	260	385 •		• M		L c	L 1	5.0	12.1		Taproot failed 18 in. below ground surface
	T.	maion (root)	510	282	339 •		• MI	м	L c	L 1	5.0	12.1	13.5	
	T	mazon (root)	154	230	317 •		• м.	м	c c	L 1	5.0	12.1	13.5	Paproot failed 12 in. below ground surface. Main stem failed sbout 40 ft sbowe ground surface
	Te	meron (root)	261	386	492 -	• •	ML	CI	-ML C	L 1	7.8	17.3	18.7	2000 To 10 SDOVE ground Surface
	Te		174	373	kri w	• •	ML	М	c c	L 1	5.0	12.1	13.5	
		ear (soil) nsion (root)	39	331	373 **		ML	CI	→E C	L 1	7.8 1	7.3	18.8 1	aproot failed 8 in. below ground surface
		ear (soii) nsion (root;	105	335	177 +	•	ML	ML	c	1	5.0 1	2.1		aproot failed 20 in, below around surface.
		ear (soii) nsion (root)	139	374 3	36 ••	• ••	ML	MI	CI	1	5.0 1	2.1		failed about 35 ft above graund surface
	1.30 Te	nsioo (stem) 3	55 6	521 6	75	•	ML	CL	-ML CI	. 1	7.8 1			tem snapped off at the pushbar height of 48 in. and fell
Cor	tinue i)						-			-	A			on top of vehicle

Nest chicle	Site No.	Te st		it Date	Tree No.	Tree Type (Common Name)	ing Height ft	Tree Height ft	Crown Oinmeter ft	Stem Dlameter id in Above- ground, in.	Work Required to Fail Tree, 1b-ft	Work Required to Override Tree, 1b-ft	Maximum Tractive Force, 1b	Meximum Horizontal Pushbar Force, ib	Maximum Vertical Pushbar Force, 1b	Pushter Height Above- ground in.	Speed at Contact uph	Haximum Longitudinai Acceleration	
1113	MACA .															Scftwood	Trees, U	nited States	(Cont
	NASA-A	144	Nov			Pine	15	35	15	7.0	*	••	0-0	9,600	3,900	38	11.2	0.90	She
	NASA-D	19	Nov	1964	78	Pine Pine	11	26	13	7)	21,640	**	**	10,050	4,600	20	0.0	**	Ela.
	NASA-E	149	Nov	-,-	180				25	7.9	47,920	**	**	19,100	7,300	50	0.0	0.15	Ten
					100	Pine	30	45	12	7.9	25,760	••	••	13,800	2,000	20	0.0	••	Sher
113	NASA-A	50	Nov	1964	41	Pine	30	49	20	7.9	†	••	**	10,500	2,500	38	0.0	••	Shea
113 1	NASA-A	43	Nov	1964	89	Pine	25	52	20	7.9	t	**	**	20,300	3,750	38	5.2	0.40	Tens
113 1	NASA-E	98	Nov	1964	129	Pine	20	48	20	7.9	•	••	0-0				5.2	0.40	Tens
113 1	nasa-e	101	Nov	1964	1.20	D4						-		18,900	4,600	36	11.6	11	Shea Tens
			NOT	*304	132	Pine	35	58	25	7.9	†	••	**	19,100	5,400	38	8.1	**	Shea
113	NASA-A	11k	Nov	1964	1.)	Pine	18	45	18	7.9	†	••	**	13,400	4,000	38	8.0	1.00	Tens
23 1	NASA-E	27	Nov	1964	2	Pine	15	42	20	8.0	33,280	**	••	14,300	h 060				
13 N	LASA-A	51	Nov	1964	56	Pine	10	46	25	ρ,					4,050	20	0.0	••	Tens
									25	8.1	†	••	**	10,300	1,450	38	0.0	**	She at
	MSA-C	59	Nov	1964	30	Pine	15	39	20	8.1	tt	••	**	**	tt	38	**	•	Shear
13 N	IASA-A	45	Nov	1964	91	Pine	30	54	30	8.2	•	••	**	11,400	3,100	38	0.0	**	Tens!
13 K	MSA-E	24	Nov	1964	81	Pine	30	51	23	8.3	54,560	••	••						Tens
13 N	IASA-A	39	Nov	1964	85	Plne	45	70	10	8.3	**	**		15,000	5,350	20	0.0	••	Shear Tens
13 N	ASA-E	153	Nov	1964	184	Pine	25	54	16	8.3			••	**	**	50	0.0	••	No Fa
13 10	ASA-A	6	Mana	106	60					0.3	36,400	**	••	17,600	1,500	20	0.0	00	Shear Tensi
	AUA-A	6	Nov	1964	60	Pine	15	47	54	8.3	t	••	**	8,150	1,400	56	0.0	0-0	Shear Tensi
13 10	ASA-A	52	Nov	1964	58	Pine	15	46	25	8.3	t	**	••	10,200	2,150	38	0.0	••	Shear
13 14	ASA-A	5	Nov	1964	61	Pine	12	48	24	8.4	1	**	**			-			Tensi
3 164	ASA-A	138	Nov	1964	169	Pine	20	60					-	8,400	2,600	56	0.0	**	Shear Tensi
	ASA-A			1964	4.4		30	60	15	8.5	•	••	**	20,800	3,700	3 8	10.2	1.20	Shear Tensi
			Nov			Pine Pine	10	56 51	20 24	8.6	57,680	**	••	18,000	6,350	50	0.0		Tensl
	ASA-E	152	Nov	1964		Pine	18	42	18	8.8	46,480	**	••	16,800	3,200	20	0.0		Tensl
	ASA-D		Nov	1964	24	Pine	30	45	30	9.0	43,920	Fit 16	**	17,400	3,850	50	0.0		No Pe
						Pine	30	36	50	9.0	33,040	**	**	12,200	2,000	20	0.0		Tensl
						Pine	30	50	50	9.1		**	**	**	**	20	0.0		Tensl
				1964		Pine	30	•-	25	9.6	**	••	**	**	**	20	0.0		No Fa:
	A-AE	54 1	lov	1964	93	Pine	40	••	30	9.6	•	**	**	••	2,050	38	0.0		No Pai
3 NA	SA-B	12	iov	1964	73	Pine	50	50	20	9.8	†	**	***	9,600	1,100		0.0		Shear
		33 1	lov	1964	50 1	Pine	15		35	10.0	**	••		••	**				Tenslo
3 NA	SA-0	33A I	lov	1964	20	Pine	15	••	35	10.0	••	**	**	**	**		0.0		No Pat
NA:	SA-B	15 8	lov	1964	76 1	Pine	18	63	30	14.0		-					0.0		No Pal
HA:	SA-B	14 N	iov	1964	35 1	Pine	35	63	25	12.1	,		-	12,600	3,500		0.0	**	Shear Tensio
									-		•	**	**	20,000	tt	100	0.0		No Fai
E-1	13 3	61 M	lay :	1964	18 0)m.k	k.	9	3	1.1	120	***		-0	III			United State	es.
NA:	SA-P	32 A				e.k		11	••	1.1	132	333	**	96	88		2.4		Elast
	SA-F	30 A	ug 1	964	46 0	e.k		13	**	1.5	152	**	**	50	**		0.0		Elesti
E-1		56 M	ny 1	964	23 0	e.k	-5	9	-3	1.5	465	815	3 630	60	+0 177		0.0		Elasti
					47 0	e.k	3	12	••	1.7	452	91)	2,632	270	177		1.8		Elasti
E-7						evthorn	1	7	3	2.0	346	1,139	1,542	200 160	**		0.0		Elasti
						u k	1	15	**	2.3	686	***	1,542		**		1.8		Elasti
MAS		S V				n.lt	••	15	**	2.5	1,500	**		340 724	**		0.0		last:
		13 Au				nik	k .	••	**	2.7 .	2,936	**	**		**		0.0		ensie
MAS	3 25	5 Ma	ly 1	964 1	rs o	nik	5	15	10	2.8	2,782	5,659	2,990	7 8 0 1,454	541		0.0 1. 7		Clast
E-1		_										/14/7	- 1770	4,77	347	EU			
E-1 E-7	41		-			evthorn	k :	15	la .	2.8	1,930	4.866			**				
E-1	3 35	6 Mm	y 1	964 1		evthorn ek		15 12	10	2.8	1,930 2,145	4,866 5,344	2,082 5,465	661 1,493	566	26	1.35	tt g	lasti

No measurement made. Total work not recorded. Instrumentation failed.

Table Bl (Continued)

eed t	Maximum Longitudina	1	7 7		Fage Con		-	Soi	USC 1 Class	CS mification	Mod	ature 2	ontest d	
tect	Acceleratio	n	0- to 6-in.		12= to	16- to 24-1n.	24- to	0- E	0 6- 8	0 12-	0 0-1	C 5- E	ontent, \$	
<u>b</u>		Mode of Pailur	e Layer		Layer	Layer	30-in.	Laye		ln. 18-1:	. 6-1r	1. 12-11	n. 18-1n	•
u, Un	ited States	(Continued)									LAY	r Layer	Layer	Rémarke
2	0.90	Shear (acil)												
	-	Tension (root)	317	518	507	••	••	ML	CL-M	IL CL	17.	8 17.3	18.8	Taproot failed 6 in, below ground surface
0	0.15	Elastic (stem)	312	702	750	••	**	SC-3	H ML	CL	12.	1 7.0	13.8	
		Tension (atem) Shear (soil)	445	693	15C	••	0-0	ML	CL	CL	12.			Undercarriage of vehicle scraped bark and wood from lower ste
0	**	Tension (root)	315	550	540	6-0	**	ML	ML	JL	15.0			Undercarriage of vehicle scraped bark and wood from lower ste
0	6-0	Shear (soil)	276	21.6						17	4)	J 26.1	13.5	Taproot failed 24 in. below ground surface
		Tenaion (ront)	510	346	519	0-0	••	ML	CL-M	L CL	17.8	3 17.3	18.7	Taproot failed 36 in, below ground aurface
5	0.40	Shear (soii) Tension (root)	385	395	378	4-0	**	ML	CL_MI	L CL	17.8	17.3	10 =	
5	**	Shear (soil)	183	287	Loc						-1.0	2113	18.7	Taproot failed 24 in. below ground surface
		Tension (root)	103	201	426	0-0	**	ML	ML	CL	15.0	12.1	13.5	Taproot failed 24 in. below ground surface
L	11	Stear (soil) Trasion (root)	101	140	256		••	ML	ML	CL	15.0	12.1	12.5	Taproot failed 36 in, below ground surface. Main stem failed
)	1.00	Tension (root)	601	===							1).0	42.1	13.5	about 38 ft above ground surface. Main stem failed
		(1000)	521	750	750	••	**	ML	CL-ML	CL	17.8	17.3	18.8	
1	##	Tension (root)	253	347	226		***	MIL	ML	CL	12.6			
1	**	Shear (soil)	20:	U.L.				_		02	13.5	11.4	14.1	Undercarriage of vehicle dragged on exposed root bulb
		Tension (ront)	291	350	391	0-0	**	ML	CL-ML	CL	17.8	17.3	18.7	Taproot failed 30 in. below ground c. rface
	+	Shear (soil) Tension (root)	253	379	387	#**	**	CL_ML	CL-ML	CI	00.0	·/ -		
	#-0	Shear (soil)						- LAPE	U LO-FIL	CL	20.2	16.2	17.5	Taproot failed 36 in. below ground surface
	**	Tension (ront)	178	253	375	0-0	**]	ML.	CL-ML	CL	17.8	17.3	18.7	Taproot failed 54 in, below ground surface
	**	Shear (soil) Tension (root)	210	284	318	**	**	-					,	
	**	No Pailure						Œ.	ML	CL	13.2	10.9	12.3	Taproot failed 30 in. below ground surface
	**	Shear (soil)	329	387	397	**	•• ,	Œ	CL-ML	CL	17.8	17.3	18.7	Vehicle immobilized
		Tension (ront)	178	292	378	••	** }	Œ.	ML	CL	15.0	12.1	13.5	Taproot failed 30 in. below ground surface
	**	Shear (soil) Tension (ront)	186	250	341	**	** }	T.	67 16		.III.			
	**	Shear (soil)			3.0			_	CL-ML	CL	18.0	15.7	14.6	Tapront failed ?6 in. below ground surface
	•••	Tension (root)	391	500	393	••	P4 N	L	CL-ML	CL	17.8	17.3	18.7	Teproot failed 36 in. below ground surface
	**	Shear (soil)	166	158	445	••	•• 🙀							
		Tension (ront)		-,0			•• н	L	CL-ML	CL	16.7	14.5	14.0	Taproot failed 10 in, below ground aurface. Undercarriage of webicie dragged on exposed root bulb
	1.20	Shear (acil) Tension (ront)	270	415	375	••	** 10	L	CL-ML	CL	17.8	17.3	18.7	- con an exposed took outs
	**	Tension (stem)	286	431	391	••	•• к	r.	CL-ML	CL				
	••	Tension (ront)	246	335	388		** 10		ML.	CL	17.8	17.3 12.1		Vehicle immobilized
		No Failure	506	277	228		** M		ML.	CIT.	15.0	12.1	13.5	Taproot failed 24 fm. below ground surface.
		Tension (root)	199	239	328		P# HD		CL	CL	11.5	12.4		Vehicle immobilized
		Tension (root)		337	326		н ж		ML	CL	15.0	12.1	13.5	Taproot failed 42 in. below ground surface Taproot failed 18 in. below ground surface
		No Pailure		299	3,4		н на	. 1	ML	CL	15.0	12.1		Vehicle immobilized
		No Failure No Failure		456			н на		CL-ML	CL	17.8	17.3		Vehicle immobilized
		Shear (soil)	318	483	545	• •	·· HE	. (CL-ML	CL	17.8	17.3		Vehicle immobilized
		Pension (root)	233	338	336	• •	e 80	-SM I	MIL	CL	6.3	7.6	11.1 t	Indercaretors of white
	**	o Failure	332	448	465 *		· MI		CL	CL	18.6	15.3		Undercarriage of vehicle scraped bark ani wood from lower stem
	**)	o Failure	332	148	465 •	• •			OL.	CL	18.6	15.3		Vehicle immobilized
		hear (soil) ension (root)	318	100	401 +		• SM	- 90	e e					Wehicle immobilized
		o Pailure						-SC N		CL	7.5	8.7	11.1	
	Inited State		411 4	218	273 •	• •	8M	-SC M	Œ	CL	8.5	6.9	6.9 V	Wehicle immobilized
		-												
		iastic (atem)	de de	60	63	BO (87 SP	-SM 8	IP-5M	SP-SM	7.3	8.2	6.9	
		lastic (stem)		40 2	240 25	3 0 36		HEL C		**		13.1	13.0	
		instic (atem)				00 50	OO CL	ML C	L-ML	0-0		14.7	14.3	
		lastic (stem)					22 SP.	SM S	P-SM	SP-5M	7.4	7.8	7.2	
	_	lastic (stem) lastic (stem)			90 54			ML C		**		13.8	14.1	
		lastic (stem)			90 11					SP-SM	3.8	4.4	4.8	
	-	ension (stem)			10 26			ML C				14.8	16.3	
		epression (stem)			60 29 30 40				L-ML			10.0	12.5	
-4		astic (stem)	200	22	92 8			ML CI					14.5	
		metic (stem)			82 9					SIP-SIM	8.7	8.1	7.9	
-0	0.07	astic (stem)			67 8					3P-5M SP-5M	3.8	4.4	4.8	
-).Ok E1	estic (stem)	86 15		57 13	-			크림 25	617-7 3 14 614	3.8	8-1	7.9 4.8	
_														

(5 of 8 sheets)



eet hicle	Site No.	Teet No.	Test	Date	Tree No.	Trea Type (Common Name)	Branch- ing Height ft	Tree Height ft	Crown Diameter	Stem Diameter 4d in. Above- ground, in.	ork Required to Fail Tree, 1h-ft	Work Required to Override Tree, 1b-ft	Hariman Tractive Force, 1b	Morisontal Pushbar Force, 1b	Maximum Vertical Pushbar Force, 1b	Puehbar Height Above- ground in-	Speed at Contact uph	Maximum Longitudinal Acceleration	Mode of
					_					3. 4 2								nited States (Continued)
37	MAPA-P	38	Aug	1964	55	Onk	7	25	**	3-7	3,724	••	**	1,580	••	26	0.0	••	Shear (eo Tension (
113	E-12	343	Huy	1964	1	Onix	4	18	1.6	3.8	5,714	8,872	3,601	4,247	639	20	2.6	-0.11	Tension (
113	E-13	387	Hay	1964	ig lig	Onik	7	21	12	3.8	5,128	13,498	6,031	1,953	613	32	1.5	-0.10	Shear (so Teneion (
37	NASA-P	41	Aug	1964	58	Onk	7	**	**	3.9	4,876	••	**	2,570	**	26	0.0	••	Tension (
113	E-13	357	May	1964	14	Ouk	6	20	12	3.9	6,523	6,898	4,476	3,264	1,155	2/3	1.9	-O.14	Shear (so Tension (
37	HASA-P	8,2,	Aug	1964	61	Onk	**	16	**	4.0	7,192	**	0.0	2,775	**	.36	0.0	**	Tension (
113	E-1 3	367	May	1964	24	Onk	6	_14	12	4.1	2,902	4,632	3,765	3,382	484	50	1.5	-0.10	Shear (ed Tension (
113	E-13	383	Hay:	1964	40	Onk	7	20	12	4.1	9,414	11,306	8,650	4,217	1,172	50	8.9	-2.06	Shear (ed Teneion (
113	E-13	359	May	1964	16	Onk	9	15	**	4.2	7,121	15,610	4,426	11	1,327	50	2.1	•0.20	Comprees
37	E-7	421	May	1964	57	Havthorn	žą.	50	15	4.3	1,712	1,865	2,101	986	**	26	1.7	**	lension (
113	E-13	372	May	1964	29	Onlt	9	50	12	4.4	††	4,881	4,363	11	679	50	2.4	-0.19	Tension
113	E-13	371	May	1964	28	Oult	7	50	12	4.5	3,792	4,386	2,833	3,792	431	50	2.2	-0.19	Shear (ed Tension (
37	HASA-P	35	Aug	1964	50	Oak	6	44	••	4.8	8,903	**	**	3,710	**	26	0.0	**	Shear (so Tension (
113	E-12	345	Mny	1964	3	Onk	3	21	5	4.8	tt	20,329	7,014	††	2,913	20	2.9	-0.50	Teneion
113	E-13	364	Huy	1964	21	Onlk	6	18	10	4.9	4,693	7.559	4,778	4,355	620	20	1.7	-0.14	Shear (e Tension
113	E-13	384	May	1964	41	Oult	6	20	12	4.9	tt	tt	**	**	††	20	**	**	Tension
113	E-13	388	May	1964	45	Onlt	6	18	15	4.9	5,287	14,304	4,048	3,425	1,513	32	2.0	-0.14	Shear (s Teneion
37	HASA-F	40	Aug	1964	57	Onk	7	27	**	5.0	7,934	••	••	2,900	••	26	0.0	••	Shear (e Tension
37	E-12	344	May	1964	2	On.k	6	21	5	5.0	9,240	14,735	6,082	3,960	1,379	50	2.5	-0.08	Tension
113	В	11	Nov	1964	49	Omit	**	40	**	5 `	†	**	**	3,400	730	56	0.0	••	Teneion
113	E-13	376	May	1964	33	Orak	6	24	6	5 1	4,804	5,2,5	4,615	3,665	613	50	1.9	-0.06	Shear (s Tension
113	E-13	389	May	1964	46	Onlk	7	20	6	5.1	7,76>	10,508	5,496	2,623	623	32	1.	-0.07	Shear (s Tension
37	NASA-P	39	Aug	1964	56	Oult	7	26	••	5.2	6,161	••	**	3,700	••	26	0.0	••	Shear (e
37	NASA-F	43	Aug	1964	60	Onak	**	20	**	5.3	12 172	**	••	4,200	••	26	0.0	••	Tension Shear (s
			-								13,173								Tension Shear (s
37	E-13	377	May	1964	34	Oult	5	27	12	5.3	14,266	18,879	4,489	5,528	1,558	20	2.2	-0.19	Tension
113	E-13	381	May	1964	38	Onk	8	50	15	5.3	21,831	23,055	6,308	8,014	3,186	20	10.3	-0.41	Shear (se Tension
113	E-13	386	May	1964	43	Onk	6	27	15	5.6	13,964	14,410	5,106	3,592	1,294	32	1.7	-0.60	Shear (se Tension
113	E-1 3	363	May	1964	20	Onk	5	24	12	5.7	10,804	11,174	9,167	4,990	2,058	20	1.2	-0.20	Shear (s
113	E-13			1964	*6	Onlt		22	15	6.1						20	10.4	•2.28	Tension Shear (s
		379					7				33,636	42,809	6,226	10,594	3,599				Tension Shear (s
113	L-13	362		1964	19	Onk	7	51	18	6.2	11	††	††	††	**	20	**	**	Tension
113	E-12	346	Hay	1964	4	Onk	45	5#	15	6.3	37,512	58,010	11,086	T. 32	2,198	۵ء	3	-0.40	Tension Shear (s
113	E-13	375	May	1964	32	Onk	11	30	12	6.3	8,100	8,401	5.981	7,436	1,139	20	2.2	**	Teneion
113	E-13	392	Hny	1964	49	Onk	12	25	12	6. 3	7,178	7,907	7,221	4,526	764	30	1.3	-0.18	Shear (s Tension
13	E-13	374	May	1964	31	Onk	6	39	13	€.5	31,309	4:,093	12,025		1,952	20	2.2	11	Shear (a Tension
113	E-13	380	May	1964	37	Onus	3	25	12	6.5	24,393	50,674	7.725	13,728	2,95)	. 0	11.4	-1.91	Shear (s
13	E-12	348		1364	6	Onik	6	27	6	6.6				8,407	1,974	20	2.1	-0.30	Tension Shear (s
.13	NASA-B	7		1964	52	Onk	16	40	18	6.7	19,752	23,573	7,215	7,900	1,700	56	0.0	•0, 50	Tension Tension
13	NAGA-A	1		1964	51	Oak	8	96	18	6.8	†	**	**	5,750	1,200	56	0.0	••	Shenr (
																			Tension Shear (
13	E-12	347	Mry	1964	5	Onk	6	27	18	6.9	10,923	13,219	6,535	6,294	2,805	50	4.9	- G. 30	Tension
13	E-13	365	May	1944	52	One	7	52	18	7.2	10,560	**	8,871	10,400	1,935	0	0	-0.33	Shear (s Tension

^{**} No meest-rement made.
† Total work not recorded.
†† Instrumentation failed

Table Bl (Continued)

nt	Haximus Longitudina		0- to	Ave	rage Cone	Index		801	1 Clas	ificatio	n N-	(atu		
	Acceleration		6-in.	12-in.	i8-in.	18- to 24-in:	24. to 30-in.	0- t 6-in	0 6-	lo 12- ln. 18-1	to G.	isture (to 12.	
	Ited States	(Continued)	Layer	Layer	Layer	Layer	Layer	Laye				12-1 er Laye	in. 18. er <i>L</i> ay	
		Shear (soii)												Vermit #8
0	**	Tension (root)	150	160	130	190	320	CL-M	L CL	L **	19.	0 17	5 42	
6	-0.11	Tension (root)	43	61	71	83	95		M SP-S					
5	-0.10	Shear (soil) Tension (root)	61	66	71		78	SP-S						.7
)	**	Tension (stem)	80	120	160	230	310				4 8.	i 6.	9 7	Tree fel: off to side and vehicle did not override the entir
9	-0.14	Shear (soil) Tension (root)	52	70	67	73			CL-H		13.	9 12.	5 13	
)	••	Tension (stem)	160	220	270		86	SP-3			8.	7 8.:	i 7.	9 Stem feil against a neighboring tree before contacting the ground
,	-0.10	Shear (soil)	55	70		330	440		CL-M	L **	12.	0 10.0	9.	4
9	-2.06	Tension (root) Shear (soil)		10	67	68	85	SP-3	SP-S	SP-SM	7.	7.8	3 7.	2
		Tension (root)	50	70	64	72	95	SP-3M	SP-9	SP-SM	5.	5.8	3 5.	2
	-0.20 ff	Compression (stem) Tension (root)	60	74	69	75	90	SP-3M	SP-SP	SP-3M	м.			
		Shear (soil)	87	130	103	98	100	314	SP-SP		3.8		, .	
	-0.19	Tenaion (root)	57	67	7*	85	92	SP-SM	SF-SM	SP-3M	9.6	7.1	7.	
	-0.19	Shear (soii) Tension (root)	59	78	78	83	92	SP-SM	CD. CM	T				
	**	Shear (soil)	310	013							9.6	7 1	7.	
	-0.50	Tension (root) Tension (stem)		550	540	540	610	CL-ML	CL-ML	**	12.8	12.1	13.6	5
	-0.14	Shear (soil)	43	68	76	74	13	SP-5M	SP-3M	SP-SM	7.5	7.6	6.1	,
	11	Tension (root)	55	74	76	77	88	SP-SM	SP-SM	SP-JM	7.4	7.0	7.2	Tree fell off to side and vehicle did not override the entire
		Tension (stem) Shear (soil)	63	70	63	73	90	SP-34	SP-JM	SP-SM	5.1	5.8	5.2	
	-0.14	Tension (root)	53	78	78	56	102 5	P-SM	SP-SM	SP-SM	b.,	6.9	7.1	The manual neight and fell forward into another to
	**	Shear (soil) Tension (root)	130	150	210	260	340 (T M7				017	1 - 4	distance of 3.0 ft
	-0.08	Tension (root)	45	67	65	65			CL-NL	**	17.3	12.3	14.7	
	• •	Tension (stem)	-12	290				P-SM C-SM	SP-SM	SP-SM	7.5	7.6	6.7	
	-0.06	Shear (soil) Tension (root)	41	80	88	99		P=SM		CL	5.4	6.8	6.8	Stem failed in tension 2 ft above ground surface
	-0.07	Shear (soil)	A. L.						or-SM	SP-SM	8.6	7.7	7.5	
		Tension (root) Shear (soil)	444	64	74	84	100 .3	P-SM	SP+9M	SP-JM	6.1	6.3	7.1	
	**	Tension (root)	500	220	210 2	00 1	yu c	-ML	CL-ML	••	17.0	19.2	. 4	
		Shear (soil) Tension (root)	190	210	200	60 4	50 CI	мт	01 44			2,00		
	-0.18	Shear (soil)					, CI	-ML	CL-PLL	**	21.2	10.3	16.5	
		Tension (root)	51	71	67	59	80 SI	-JH .	SP-SM	SP-3M	*.¢	7.7	7.5	
	- 1.41	Shear (soil) Pension (root)	59	80	78	58	× SP	-SM .	P-ON	SP-JM	6.8	5.9	2	
		Theu. (soil) Tension (root)	53	65	7 5 9	1 6 1	Y					219	5.9	
		Rear (soil)		-,	0		e sf	-324 5	P-:M	SF-JM	***	6.9	7	Stem appeared infectes at take
	7	ension (root)	48	66	71 1	16	34 SP	-3M .:	P-3M	S.?3M	1.4	7.8	7.2	
		hear (soii) ension (root)	60	71	73 7	3 8	7 SP	-JM &	Pullan :	SP- 2M	6 4	,		
		hear (soil)	51	67	7 5 - 8						6	5.9	- 3	
	0.10	ension (root) ension (root)						.aM S		SP. M	7. •	1.6	6 3	Tree feel off to size and vehicle til not ventile the entire crown.
	tt S	hear (soil)			74 9		SP.	SM 3	P=3M	SP-IM	€.0	7.5	5.1	
	T	ension (root) hear (suil)	54	75	78 90	9	sp.	SM SI	P-5M	SP-St	4.6	7.7	7.5	
-		maion (root)	70	97 9	5 10	11	P-	SM SI	-SM	SP-DM	1	6.5	6.1	
		mear (soil)	58 7	79 7	6 BC	, 2,	9 '5	M						
_	1.91 5	ear (soil)					F-	om di	W	3P+JM	".6	7.7	1.5	
	Te	nsion (root)	65 7	19 7	4 73	*	SP.	OM SP	-UM	JP34	e .	5.3	5. 4	Tree faller + ft above grund unface an fe lear f f veh cie
-1		ear (soil) nsion (root)	6a 9	3 9	5 yes	lue	SF=.	DM SE	-34	Fe.M	£	7.		
			10 27	5 27		••		71; NC		L				Tree appeared to be infected
		ear (soii) nsion (rcot)	60 °1	1 40	7 ••	••	ME.					. ~	7.5	
+(). 30 Sh	ear (soil)							-~L (L	1.4	it.U	15.1	
	Te	nsion (root) '	43 6) 7°C) 14	100	SF-	M UP	-IM s	P= 2M	6.0	1.	1.1	
-0		rar (soii) usion (root)	0 70	58	75	95	SF-J	M SP.	. Mr.	P+ 24	7. 1		6.9	Tree was entirely uprooted or a ranged sementh webic e for a
													4.9	il tarce of 1 . ft

B

(f heets)

1113 E 1113 E 1113 E 1113 E	E-13 E-12 E-13 E-13 E-13 E-13 E-13	390 349 358 378 393	Huy Huy Muy Huy	1964	47					ground, in.	Tree, li-ft	Tree, lb-ft	Force, lb	Force, lb	Force, 1b	ln.	undep		
1113 E 1113 E 1113 E 1113 E	E-12 E3 I-13 E-13	349 358 378	May		47											Hardwood	Trees,	United States	(Continue
1113 E	E3 1-13 E-13	358 378	May	1964		CIPAR	6	25	15	7.3	16,159	34,231	9,891	8,407	1,615	32	1.8	-2.40	Shear (
113 E	H=13 H=13 H=13	378	50-		7	Onk	5	27	20	7.5	32,910	13,268	11,446	11,977	3,195	20	2.3	-0.39	Shear (
113 E	E-13 E-13		May	130h	15	Oak	6	24	20	7.6	55,487	81,198	14,556	12,078	3,566	20	1.5	-0.34	Shear (
113 E	E-13	393		1996	35	Onk	7	55	15	7.8	48,238	50,888	8,090	21,672	6,513	.40	11.4	-2.20	Tension
113 H			May	1964	50	Onk	6	21	5#	7.8	17,119	62,725	11,546	7,695	1,380	32	1.1	-0.23	Chear (
113 N	B-13	368	Mny	1964	25	Onk	6	24	20	8	17,090	19,768	9,910	7,300	2,008	20	0.9	-0.20	Shear (
		391	Mny	1964	48	Onk	6	30	54	3.3	28,125	48,866	9,758	8,320	1,318	32	4.9	-1.08	Shear (
113 E	Kasa-a	2	Nov	1964	54	Onk	12	l _k l _k	23	8.5	•	••	••	8,900	2,550	56	0 0	••	Shear (Tension
	B-12	350	May	1964	8	Onk	8	24	12	8.6	21,029	22,857	11,577	10,971	2,399	20	1.4	-0.39	Shear (
113 E	E- 13	385	Hny	1964	42	Onli	7	27	5#	8.6	∌,679	105,539	11,528	12,515	2,552	34	2.1	u2.54	Shear (
113 E	B-13	382	May	1964	39	Onk	7	25	18	9.0	45,656	65,514	11,490	23,846	5,805	20	8.9	-2.00	Tension
113 E	E-13	360	Hny	1964	17	Omit	6		18	9.3	35 hah	50,982	11,484	13,159	5,477	50	2.3	-0.54	Shear (Tension
113 E	E-13	36,	May	1964	26	Onk	6	27	24	9.4	43,539	82,948	15,072	14,080	3,800	.20	1.7	-0.47	Shear (Tension
113 8	L -13	394	Mny	1964	51	Omk	10	30	24	10.2	††	**	**	**	**	32	**	**	Shear (Tension
113 E	B-12	354	Hay	1964	11	Onk	5	27	14	10.8	35,119	45,755	16,866	15,020	2,396	20	1.3	-0.60	Shear (Tenslor
113 E	E=13	370	May	1964	27	Onk	10	33	18	11.4	55,903	88,452	16,438	20.617	2,884	50	2.2	-0.70	Shear (Tension
113 F	1-12	152	May	1964	10	Onk	9	33	20	11.5	* *	**	17,018	**	††	*0	**	11	
	R-12	353	Mny	1964	10	Onk	9	33	20	11.8	84,066	107,882	13,303	35,400	4,944	50	5.0	•0.29	Shear (Tension
	E-13	395	μ.	1964	52	Onk	4	30	18	12.9	11	11	16,885	**	16,652	3.2	2.0	11	Shear (
113 II	E-13	396		964	5c	Onk		30	18	12.9	11	103,364	17,112	**	**	32	3.0	oc. 309	Tension
																	:- ndwoo	d Trees, Thai	land
	5V-S-1 5V-8-1	53	1112	1965 1965	37	Hieng Hieng	6	9	2	2.0	221 2 9 9	**	**	188	53 72	20	2.2	0.0	Elastic
	5V-8-1	8		1965	6	Hieng	5	15	la la	2.0	310	**	**	116	41	32 32	1.7	11	Tension Compres
113 5	5V-8-1	7	Sept	1965	5	Biar .	10	12	5	2.2	408	**	* *	164	49	34	1.4	0.03	Einstic
0.13 5	5V-S-1	2	Sept	1965	2	Hieng	6	15	2	2.3	11	**	* *	170	65	32	1.6	**	Tension
113 5	5V-8-1	23	Sept	1965	16	Hieng	12	15	5	2.3	795	**	1,603	408	11	32	2.1	11	Compres
1113 5	5V-8-1	30	Sept	1965	26	Rieng	10	18	in .	-2.7	1,670	1,889	2,836	718	146	32	1.9	0.00	
u13 5	5 V-S- 1	65	Sept	1965	60	"leng	7	15	6	2.7	2,750	**	**	750	310	20	2.0	† *	Elastic
u13 5	5V-8-1	3	Sept	1965	3	Hieng	13	17	6	2.9	1,239	6,195	5,053	516	550	32	1.6	**	Tencion
u13 5	5 V =8-1	56	Sept	1965	11	Hieng	6	50		2.9	1,458	**	tt	999	302	32	2.1	* *	Tension
u13 5	5V+S+1	6	Sept	1965	9	Riens	8	21	6	3.1	1,797	**	**	653	362	32	1.8	††	Shear (Tension
1113	5V-S-1	29	Sept	1#5	27	Hieng	7	15	5	3-3	2,713	**	3,858	1,305	416	32	1.7	0.03	Shear (Tension
113 5	5V-8-1	10	Sept	1965	24	Hieng	7	18	12	3.5	2,430	**	3,30€	1,170	413	32	1.6	0.04	Shear (Tension
113 5	5 V-S- 1	31	Sept	1965	35	Hleng	6.	15	la .	3.9	3,295	7,779	≥,785	1,147	318	3.	ć	0.04	Shear (Tension
113 5	5V-S-1	59	Sept	1965	57	Hieng	10	18	6	3-9	3,073	9,952	2,858	1,260	583	20	2.1	0.07	Shear (Tension
113 5	5V-S-1	5	Sept	1965	8	Hieng	1.2	25	9	4.0	≥,Π≥	5,634	2,391	94 =	360	34	2.0	0.08	Shear (Tension
113 5	5 V- 8-1	16	Sept	1965	12	Hieng	5	21	8	4.0	3,400	7,35%	3,955	1,405	tt	3/	2.1	0.10	Shear (Tension
113 5	5V-S-1	27	Sept	1965	25	Hieng	7	21	15	4.0	3,763	5,350	3,300	1,845	1,510	3.	2	0.12	Shear (Tenslor
113 5	5¥-S-1	32	Sept	1965	34	Hieng	7	21	6	4.0	5,472	**	**	1,613	600	32	2.1	o. uś	Shear (
113 5	5 V- S-1	56	Sept	1965	55	Bieng	7	21	7	4.3	4,940	5,500	2,664	2,282	717	20	2.4	0.13	Shear (
																			141:0100

^{••} No measurement made:
† Total work not recorded:
†† Instrumentation failed.



Table B1 (Continued)

Speed	thur ima		-	Av	ruge Con.	Index		C. 4	USC					
Contact		ion	6-1r	00 P- EC	12- to	18- to	24- to	0-1	0 b- to		0 D- to	ture Con	test,	
apb_		Mode of Pailu	re Laye			Laye	30-in. Layer	6-in		. 18-1n	6-14.	le-in.		
ees, t	United Stat	es (Continued)							33,41	Ayer	Layer	LAYER	Laye	Rem ***
1.8	-2.40	Shear (soil)	41	0.	-									
		Tension (root)	61	. 83	76	96	115	SP-S	SP-S	SP-SM	8.1	6.5	6.	1
2.3	-0.39	Shear (soil) Tension (root)	64	83	89	102	100	SP-9	SP-SM	68 m				
1.5	≈0. 3k	Shear (soil)	50					04-0	01-434	8P-3M	6.6	5.8	5.	5
11.4	-2.20	Tension (root)	50		66	83	95	SP-3	SP+SM	SP-34	8.5	4.0	7.	
		Tension (stem) Shear (soil)	47	65	72	78	89	SP-S	SP-SN	SP-SH	н.е	7.7		
1.1	-0.23	Tension (root)	59	81	87	95	106	SP-SN	SP-SM	SP-SM			7.	resident neight and fell on top of vehicle
0.9	-0.20	Shear (soil)	57	21						20 - CBP	8.1	6.5	ė ,	()
		Tension (root) Shear (soil)	,,	71	75	92	107	SP-SM	SP+SM	SP-SH	7.3	9.2	6.9	
1.9	-1.06	Tension (root)	42	62	83	91	92	SP-SM	SP-2M	SP+SM	9.1			
0.0	0-0	Shear (soil)	145	162						me was	0.4	6.5	0.4	
		Tension (root) Shear (soil)	24)	102	178	••	**	ME	CL-ML	CL	12.0	16.0	20.0	
1.4	-0. 19	Tension (root)	47	64	67	83	104	SP-3M	5.2 -5M	SP-SM	4 0			
2.1	-2.54	Shear (soil)	67	000						est in sing	6.8	5.8	5.6	
.9	-2.00	Tension (root) Tension (stem)		90	97	96	115	SP-SM	SP-SN	SP-SH	5. 4	4.8	5.4	
. 3		Shear (soil)	58	75	79	91	105	SP-SM	SP-SM	SP-SM	6.8	5 ,	5.9	Tree fallet a in, above ground surface and fell forward :
	≈0.5h	Tension (rout)	48	67	73	83	103	SP-JM	SP-SN	SP-3M	8.5	н		another tree
-7	-0.47	Shear (soli)	52	81	96					01 - 01	0.7		7. *	
•		Tension (root) Shear (soil)	/-	0.	340	99	104	SP-3M	SP-SM	SP-3M	9 6	7.1	7 1	
	**	Tension (-oot)	59	81	94	111	129	SP-SM	SP-SM	SP-SM	8.1	6 6		
. 3	-0.60	Shear (soil) Tension (root)	61	83	84	0.3					0.1	6.5	6 . 7	
. 2	0.20	Shear (soil)		0,5	1.7	93	95	P-SM	SP-SM	SP-SM	8.1	7 €	4	
	-0.70	Tension (root)	62	86	37	101	109 8	P-SM	SP-SM	SP-SM	9.6	7.1	2	
	* *	••	64	83	89 1	02	.00 s	P-SM					7 - 4	
0	-0.29	Shear (soii) Tension (root)	64	83	89 1			P-SM (SP-SM	6.8	5.8	- 6	Vehicle inmobilize:
0	**	••	63	107						SP-SM	6.8	5.8	5.4	
0	-2.309	Shear (soil)					85 SI	SM :	P-94	SP-SM	5, 1	5.8	5.6	Vehlcle (mmobilize)
		Tension (root)	63	107	155	7' 1	B5 S1	-SM S	P-SM	SP-3™	5.1	5.8	5.2	Vehicle immobilize:
wood Ti	rees, Thal.	land												THE PARTY OF THE P
7	0.0	Elastic (stem)	175	199	186 1	2								
	* *	Tension (stem)	167		275		SN SN		L-MI,			7.0	15.4	
	0.03	Compression (stem)	185	289	246 ••	•			i⊶mi, i⊶mil	••			••	dehicle hull contacted stem before the pushban has complete the stem falsure
	11	Einstlc (stem)	201	500	97 ••	•							3.4	
	**	Tension (slam) Compression (stem)			42	••	SM			••			4.7	Vehicle hus, contected stem teffer the pushbor had to the stem fall to
	0.02	compression (stem)			69 13		4 314	CI	-ML	••	6.9			
	* *	Elastic (stem)			•		SM	CI	-ML	••	••		••	tem appeared to be infected at base
	**	Tension (stem)			74		SM			••	••	•	••	
	11	Shear (soil)				••	SM	CL	-ML	••	••	•	••	
		Tension (root)	199	192 1	95 ••	••	594	CL	-ML ·	1	7 15	.5 15	. 9	Tree appeared to be infected
	* *	Shear (soii) Tension (root)	191 2	248 10	53 ••	••	594	CL	.ur		. 7			ALL VICTORY
	0.03	Shear (soil)	166 1					U.D.	-HL 1		7 11	. 5 15	. 9	
		Tension (root)	100]	196 21	1 216	501	SM	CL	MI	• /	7.1 17	, 4 1t	. 1	
	0.04	Shear (soil) Tension (root)	187 2	51	2 172	160	SM	CL	ML .	. 16				
	0.04	Shear (soll)	163	J 15	3			-	· •		17	. 1 15	. *	
		Tension (root) Shear (soil)		J 15	2 229	3<7	34	CL-	ML .	16	. U lt.	7		
	0.07	Tension (root)	184 1	96 13	5 182	169	30	CL	HL e					
		Shear (soil)	186 20	68 19	4					: e	t it.	4.	. 46	
		Tension (root) Thear (soil)	(1	19		••	SIM	CL-	ML 04	.6	7 15.	5 . 6.	, L	tire crows was not overriiden que to short departure lane
(Pension (root)	142 20	201	••	••	514	CLos	4L ••					- reason us to short teparture take
(Shear (soll)	184 23	A 16						1º	.0 14.	14.		
		Mension (root) Thear (soil)	-5-	18	170	117	314	CL-	L	17.	1 17.	4. 6.	Ł	
	0.08	ension (root)	196 23	191	143	132	F3M	CL	Œ	7.0			2	
C	.13	hear (soil)	179 24	A 370	10.					1	9 17	+7-	ſ	
	1	ension (root)	1.7 (19	8 275	283	7,019	SM:	Cal	IL ••	14.	7 17.	16.	9	

Tret /ehicle	Site No.	Test No.	Test Date	Tree	Type (Common Name)	ing Height ft	Tree Beight ft	Crown Diameter ft	Diameter 421n. Above- ground, in.	Work Required to Fail Tree, ib-ft	Work Required to Override Tree, 1b-ft	Haximar Tractive Force, ib	Horizontal Pushbar Force, 1b	Vertical Pushbar Force, 1b	Heighs Above- ground in-	Speed at Contact uph	Maximum Longitudinai Acceleration	
															Hardwood	Trees,	Thailand (Cont	inued)
H113	5V-8-1	55	Sept 1965	22	Bleng	12	54	8	4.5	2,930	4,671	3,768	2,363	1*	32	2.2	0.09	Shear (
M113	9V-8-1	60	Sept 1965	58	liteng	9	21	: 8	4.5	**	tt	**	+ +	**	50	**	**	Shear (Tension
M113	5V-8-1	п	Sept 1965	14	Hiung	9	24	15	4.6	4,814	7,886	4,668	2,657	722	32	1.9	0.12	Shear (
M113	5V+S-1	9	Sept :965	10	Hieng	7	33	10	4.7	8,533	41,504	2,417	2,893	772	32	1.4	0.12	Shear (
H113	5V-8-1	19	Sept 1/65	32	Hieng	5	15	12	4.8	3,452	22,469	3,8.6	1,678	493	32	1.7	0.15	Shear (
M113	5Y-S-1	40	Sept 1965	43	Hieng	15	30	10	4.8	3,504	4,270	3,092	4,373	1,011	20	1.9	0.12	Compres
M113	54-8-1	55	Sept 1965	53	Hleng	9	25	12	4.8	4,230	5,792	3,535	2,821	1,980	50	1.7	0.24	Shear (Tenslos
4013	5V-8-1	50	Sept 1965	33	Hieng	8	27	8	4.9	7,283	tt	3,021	992	7:	32	2.1	0.08	
M113	5V-S-1	61	Sept 1965	59	Bleng	10	24	7	4.9	8,700	8,090	4,386	2,472	648	50	2.1	0.10	Shear (
M113	5Y-8-1	21	Sept 1965	23	Hleng	10	27	11	5.0	6,009	7,244	5,855	2,744	720	32	2.0	0.10	Shear (
H113	5V-8-1	35	Sept 1965	36	Hieng	10	25	10	5.0	9,179	17,864	4,135	2,904	1,165	50	1.9	0.10	Shear (Tension
H113	5V-S-1	47	Sept 1965	47	Hieng	8	27	6	5.0	5,400	11,050	4,560	3,460	903	20	2.0	0.18	Shear (
M113	5V-S-1	28	Sept 1965	28	Hieng	11	33	14	5.1	7,130	9,100	**	11	1,239	32	2.0	**	Shear (
H113	5Y-8-1	54	Sept 1965	52	Hleng	8	24	8	5.1	8,453	34,188	5,463	5,441	2,567	20	2.0	0.20	Tension Shear (
M113	5V-8-1	13	Sept 1965	19	Hieng	7	30	8	5.6	6,621	24,555	8,846	7,040	816	32	1.7	0.16	Tenslos
H113	5V-8-1	39	Sept 1965	44	Hierg	15	30	8	5.8	11,220	18,156	4,606	4,034	988	20	2.0	0.14	Shear (
M113	5V-S-1	57	Sept 1965	56	Bieng	10	30	9	5.8	6,906	13,425	4,350	4,682	938	50	2.1	0.21	Shear (
H113	5V-8-1	58	Sept 1965	54	Hieng	12	30		6.0									Tension Shear (
					0.521			13		14.723	18,494	10,957	6,590	1,080	20	1.6	0.22	Tension Shear (
M113	5V-8-1	17	Sept 1965	51	Hleng	10	27	5	6.1	5,440	7,952	5,153	3,956	589	32	2.0	0.16	Twnsloa
M113	5V-8-1	46	Sept 1965	41	Hleng	10	25	5	6.1	6,736	8,964	2,815	4,030	672	50	1.7	0.06	Shear (Tenslos
M11.3	5V-8-1	12	Sept 1965	13	Hleng	9	33	14	6.4	14,435	20,166	5,365	5,120	1,130	32	1.7	0.16	Shear (Tension
411 3	5V-8-1	15	Sept 1965	18	Hleng	10	33	8	6.4	8,600	9,701	4,061	4,785	667	32	1.8	0.19	Shear (
1113	5V-8-1	42	Sept 1965	40	Hleng	7	28	5	6.4	9,563	22,375	6,420	3,612	1,350	50	2.0	0.19	Shear (
1113	5Y-8-1	37	Sept 1965	45	Hieng	7	30	8	6.7	10,175	15,957	6,423	6,929	1,870	50	1.9	0.27	Tension
013	5V-8-1	36	Sept 1965	42	Hieng	9	30	15	7.2	12,892	17,649	7,258	6,512	925	50	1.8	0.31	Tenslos
013	5Y-8-1	· A	Sept 1965	h	Hleng	8	34	5/1	7-3	12,686	18,017	9,749	9,263	1,015	32	2.2	0.32	Tenston
413	5Y-8-1	18	Sept 1965	и	Hien;	T	30	10	7.4	15,018	50,385	6,045	5,497	2,040	32	2.5	0.24	Shear (
a 13	5V-8-1	38	Sept 1965	46	Hieng	9	32	8	7.4	14,413	34,197	7,164	10,533	1,845	50	2.3	0.47	Shear (
0113	5V-8-1	48	Sept 1965	48	Hieng	4	25	14	7.5	14,932	16,513	7,959	7,121	1,481	50	1.8	0.31	16 10100
a 13	5V-8-1	41	Sept 1965	38	Hieng	10	25	16	8.0	26,588	93,331	14,942	7,861	2,096	50	2.1	0.33	Shear (
u 13	5V-8-1	14	Sept 1965	20	Hieng	12	45	24	8.4	23,650	27,056	7,652	7,555	1,896	32	2.3	0.26	
013	5Y-8-1	49	Sept 1965	49	Hleng	6	26	15	8.8	25,304	11	tt	11,634	1,836	50	1.9	0.42	Shear (Tenslos
a 13	5V-8-1	43	Sept 1965	39	Hleng	15	35	16	9.1	**	**	**	11	**	50	**	**	Shear (Tenslos
1113	5V-8-1	52	Bept 1965	61	Hieng	12	30	12	9.1	25,650	55,506	13,509	14,947	3,341	50	2.2	0.73	Shear (
113	57-8-1	24	Sept 1965	15	Hieng	10	45	11	9.6	**	tt	11	11	**	32	**	**	Compres
113	5V-8-1	33	Sept 1965	30	Hieng	8	40	14	9-7	26,854	38,522	12,171	14,523	1,298	32	2.2	0.59	Shear (
1113	5Y-S-1	50	Sept 1965	51	Hleng	15	35	20	10.0	50,582	101,238	21,644	17,248	4,150	50	1.7	0.62	Shear (Tenslos
1113	5V-S-1	51	Sept 1965	50	Hieng	50	45	10	10.7	42,329	101,796	18,368	21,961	4,425	50	3.4	0.99	Shear (
113	5 V -8-1	36 1	Sept 1965	29	Hieng	11	45	15	13.0	46,640	150,544	16,539	17,466	4,296	50	1.5	0.72	Shear (Tension

^{••} So measurement made.

11 Instrumentation folled.

Table Rl (Concluded)

Speed	Harlman			Ave	rage Com	Index		Solf	CLassif	testion	M 4	***** A:		
at	Longitudinal Acceleration		0- to 6-1n.	6- to	12- to	16- to	24 - to	C- to	6- to	12- to	0- to	ture Con	12- to	
mig		Mode of Pailure	Layer		18-in.	in in	30-ln. Layer	6-in.	la-in.	18-in.	6-in. Layer	12-in.		
rees, T	hailand (Conti	iqued)												Remarks
2.2	0.09	Shear (soil) Tensico (root)	159	213	200	155	186	SH	C!_ML	••	18.0	17.2	17.0	
**	**	Shear (soil) Tensico (root)	**	**	••	**	••	814	CL-ML	••	••	**		Entire crown was not overridden due to short departure lane
1.9	0.12	Shear (soll) Tension (root)	178	214	176	159	184	148	CL-ML	••	16.2	16.7	16.4	
1.4	0.12	Shear (soil) Tension (root)	509	245	183	**	**	SM	CL-ra	6.0	16.5	17.1	16.0	
1.7	0.15	Shear (soil) Tension (root)	160	180	172	147	152	594	CL-HL		17.0	17.8	16.8	Tree fell off to side and vehicle did not override the entire
1.9	0. 12	Compression (stem) Shear (soii)	159	153	172	184	192	814	CL-ML	**	11.8	22.5	15.3	
1.7	0.24	Tensico (root)	179	248	275	283	294	34	CL-ML	**	14.7	17.3	15.9	
2.1	0.08	Shear (soil)	176	506	160	111	140	341	CL-ML	**	16.2	16.4	16.5	
2.1	0.10	Tension (root)	**		••	••	**	SM	CL-ML	**		**	••	
2.0	0.10	Shear (soil) Tension (root)	191	505	164	179	195	SH	CL-ML	••	18.0	17.2	17.0	
1.9	0.10	Shear (soil) Teneloo (root)	168	166	155	137	150	S14	CL-ML	••	15.5	15.7	16.2	
2.0	0.18	Shear (soil) Tensioo (root)	133	159	150	185	565	3 4	CL-ML		14.1	13.4	16.1	
.0	* *	Shear (soll) Tension (root)	166	196	211	216	501	34	CL-ML	••	17.1	17.4	16.1	
.0	0.20	Shear (soll) Tension (root)	172	194	199	227	243	SM .	CL-HL		14.7	17.3	15.9	
.7	0.16	••	179	221	221	187	191	SH	CL-HL		16.6	16.0	14.9	
.0	9.14	Shear (soil) Tension (root)	154	162	164	159	181	3 M	CL-ML	**	11.8	22.5	15.3	
.1	0.21	Shear (soil) Tension (root)	179	248	275	263	294	SH	CL-MJ.		14.7	17.3	15.9	Entire crown was not overridden due to short departure lane
.6		Shear (soil) Twnsico (root)	172	194	199	227	243	SH (CL-ML	**	14.7	17.3	15.9	AMERICAN CONTRACTOR OF STREET
0		Shear (soil) Twnslon (root)	137	170	18.	174	173	SM (CL-ML		16.6	16.2	15.4	
7	0.06	Shear (soil) Tensloo (root)	199	179	160	174	162	9K (CL-ML	••	16.0	17.1	18.7	
7		Shear (soll) Tension (root)	130	193	178	159	187	SH (i -ML	••	16.2	16.7	16.4	
8	V.129	Shear (soll) Tensloo (root)	176	167	134	146	183	SM (K-ML	**	15.4	14.6	14.2	
0		Shear (soll) Tension (root)	144	136	155	203	175 8	3H C	L-ML	**	16.0	17.1	18.7	
9		Tension (root)	154	171	192	180	186 8	и с	L-ML			18.3	17.9	
8	0.32	Shear (soil) Tension (root)	159	161	141	128	135 8	e c	LHL	••		22.5	15.3	
2		Shear (soil) Pension (root)	152	192	211	**	•• 8	н с	L-ML	••	**	**		
5		Shear (soll) Tension (root)	144	157	137	143	193 8	н с	L-ML	••	16.4	16.4	17.9	
3		Shear (soil) Tension (root)	125	143	159	177	185 S	н с	L-ML		15.6	18.3	17.9	
8	0.31	**	148	139	188	248	235 8	н с	L-ML			17.4	16.1	
1		Shear (soil) Twnsion (root)	121	120	137	153	179 8						18.7	
3	0.26		157	219	234	210 :	275 8	H C	L-ML (14.9	
9	7	Auston (LOOF)	142	194	214	216	255 B	H C	L-ML				16.1	
		bear (soil) busion (root)	138	130	110	131	149 8	4 C	Ludelly 1	10	15.6	18.3	17.9	
2		hear (soll) ension (root)	141	162	207	173	168 a	4 CI	L-ML 4	н	7.1	17.4	16.1	Undercerriage of vehicle dragged on exposed root bulb
			167	204	165	153 1	169 1	4 01	L-ML .	•	6.8	16.4		Stem appeared to be infected at base
?	T. 25	amazon (root)	176	223	221	193	159 5	e ci	ML .	•	6.4	15.9		Indercarriage of vehicle dragged on exposed root bulb
7	1	ematon (root	145	166	201 2	232 2	27 3	e cr	-ML •		7.1	17.4	16.1	
	T. 37	anaton (FOOC)	175	198 :	214 (P43 2	19 8	c cı	-ML •	•	7-1	17.4	16.1	
5		hear (soll) ension (root)	175	241 :	211 1	199 2	09 3		-ML .	•	6.4	15.9	16.4 F	ront portion of tracks raised off the ground to complete

(8 of 8 sheets)



Summary of Data and Test Results, Bamboo Override Tests

W-SBO 32 0.500 13.5 * <	W.SBO 32 0.550 13.5 ** * * * * ** * ** *	Teat	Test	No. of	" A	Clump Diameter	Wor Required	Contact	Maximum Horizontal Pushbar Force	Meximum Longitudinal Acceleration	Sod 0- to 6-	Soils Data, Average Cone Index	erage	to 18-
WV-SBO 32 0.500 13.5 **	W-SBO 32 0.500 13.5 * <	No.			1	th.	Clumb,	u din	136	8	in. Layer	in. Layer	in.	Layer
W-SBO to 0.375 19.0 1183 1.5 734 0.155 ty-SBO 35 0.590 21.5 3150 2.2 1405 0.207 ty-SBO 34 0.500 34.4 6950** 2.7 2873 0.177 ty-SBO 54 0.500 34.4 6950** 2.7 2873 0.193 ty-SBO 17 0.550 32.6 5223 1.7 2873 0.197 ty-SBO 17 0.550 32.6 5223 1.7 2288 0.193 ty-SBO 17 0.370 9.5 506* 516 2.4 210 0.180 ty-SBO 18 0.370 13.3 276 1.7 175 0.100 ty-SBO 16 0.550 10.5 7 7 1.7 1.7 1.7 1.7 1.10 0.100 ty-SBO 16 0.500 13.3 250** 1.9 200 0.100<	W-SBO % 0.375 19.0 1183 1.5 734 0.155 130 139 139 139 144 W-SBO 4.4 6.950*** 2.2 14.05 0.155 130 139 139 139 139 139 139 144 4.4 6.950*** 2.2 14.05 0.150 150 120 170 2.2 14.05 0.250 13.4 6.950*** 2.7 2873 0.193 110 115 120	227	4V-SBO		0.500	13.5	*	*	*	*	100	112	10	35
W-SBO 35 0.500 21.5 3150 2.2 1405 0.207 W-SBO 36 0.570 34.4 6950++ 2.7 2288 0.133 W-SBO 47 0.550 32.8 7800++ 2.7 2288 0.131 W-SBO 47 0.550 32.8 7800++ 2.9 2988 0.131 W-SBO 17 0.570 32.8 7800++ 2.9 2988 0.131 W-SBO 17 0.370 9.5 516 1.8 216 0.150 W-SBO 17 0.370 10.5 728 1.7 177 0.105 W-SBO 16 0.500 13.3 206 1.8 278 0.105 W-SBO 16 0.500 13.3 206 1.8 2.0 0.100 W-SBO 16 0.500 13.3 206 1.8 2.0 0.100 W-SBO 12 0.500 11.8	ty-SBO 35 0.500 21.5 3150 2.2 1405 0.207 113 144 ty-SBO 34 0.500 25.2 3150 2.2 1405 0.240 113 114 ty-SBO 34 0.500 32.2 32.4 2500** 2.7 288 0.191 110 115 ty-SBO 17 0.550 32.6 52.23 1.7 288 0.191 106 124 ty-SBO 18 0.370 9.5 516 2.4 210 0.191 106 114 ty-SBO 18 0.370 9.5 516 1.8 276 0.106 113 116 117 117 0.106 113 116 117 117 0.106 113 116 117 118 276 0.106 113 117 118 276 0.106 113 117 118 276 0.106 113 118 118 118 <th< td=""><td>88</td><td>4V-SBO</td><td></td><td>0.375</td><td>19.0</td><td>1183</td><td>1.5</td><td>734</td><td>0.155</td><td>130</td><td>130</td><td>14</td><td>110</td></th<>	88	4V-SBO		0.375	19.0	1183	1.5	734	0.155	130	130	14	110
ty-SBO 30 0.750 25.2 7102 2.0 1770 0.240 ty-SBO 54 0.500 34.4 6950** 2.7 2873 0.478 ty-SBO 57 30.6 5223 1.7 2288 0.193 ty-SBO 37 9.5 32.8 7800*** 2.9 2988 0.193 ty-SBO 18 0.570 32.8 7800*** 2.9 2988 0.193 ty-SBO 17 0.370 7.6 645 1.8 276 0.162 ty-SBO 18 0.570 10.5 728 1.3 276 0.105 ty-SBO 16 0.550 13.3 2060 1.7 175 0.100 ty-SBO 16 0.550 13.3 2060 1.8 2.1 0.100 ty-SBO 16 0.550 11.3 350 1.9 2090 0.160 ty-SBO 16 0.550 11.6 <th< td=""><td>ty-SBO 30 0.750 25.2 7102 2.0 1770 0.240 0.240 105 120</td><td>83</td><td>4V-SBO</td><td></td><td>0.500</td><td>21.5</td><td>3150</td><td>2.5</td><td>1405</td><td>0.507</td><td>3.5</td><td>गुना</td><td>12</td><td>) ~</td></th<>	ty-SBO 30 0.750 25.2 7102 2.0 1770 0.240 0.240 105 120	83	4V-SBO		0.500	21.5	3150	2.5	1405	0.507	3.5	गुना	12) ~
tV-SBO 54 0.500 34.4 6950*** 2.7 2873 0.178 tV-SBO t7 0.550 30.6 5223 1.7 2288 0.193 tV-SBO 37 0.550 32.8 7800*** 2.9 2988 0.191 tV-SBO 18 0.370 9.5 516 2.4 298 0.191 tV-SBO 17 0.370 9.5 516 2.4 298 0.191 tV-SBO 17 0.370 9.5 516 1.7 175 0.100 tV-SBO 16 0.500 13.3 206 1.7 175 0.100 tV-SBO 16 0.500 21.3 206 1.8 2.0 0.100 tV-SBO 12 0.500 21.3 3553** 1.9 209 0.150 tV-SBO 12 0.500 21.3 3553** 1.9 200 0.100 tV-SBO 16 0.500	W-SBO 54 0.560 34.4 6950+** 2.7 2673 0.476 96 117 W-SBO 37 0.550 32.6 7800*** 2.9 2988 0.193 110 115 W-SBO 18 0.550 32.6 7800*** 2.9 2988 0.193 106 124 W-SBO 17 0.370 37.6 5.16 2.4 210 0.193 110 115 W-SBO 17 0.370 37.6 1.6 1.7	230	4V-SBO		0.750	25.2	7102	2.0	1770	0.240	305	061	727	
tV-SBO tr 0.550 30.6 5223 1.7 2288 0.193 tV-SBO 37 0.550 32.8 7800** 2.9 298 0.191 tV-SBO 18 0.370 9.5 516 645 1.8 276 0.180 tV-SBO 12 0.400 8.3 370 1.7 175 0.100 tV-SBO 12 0.400 13.3 2060 1.8 276 0.160 tV-SBO 16 0.500 13.3 2060 1.8 1250 0.100 tV-SBO 16 0.500 13.3 2060 1.8 1250 0.100 tV-SBO 16 0.500 11.8 825 2.0 401 0.165 tV-SBO 12 0.500 11.8 825 2.0 401 0.200 tV-SBO 22 0.500 11.6 2460 2.2 401 0.200 tV-SBO 36 0.500 <td>WV-SBO 17 0.550 30.6 5223 1.7 2288 0.193 110 115 WV-SBO 18 0.550 32.8 7800** 2.9 298 0.191 106 124 WV-SBO 18 0.370 7.6 645 1.7 775 0.180 123 116 124 WV-SBO 12 0.400 13.3 200 1.7 177 0.100 143 121 WV-SBO 16 0.500 13.3 200 1.8 326 0.100 143 136 WV-SBO 16 0.500 13.3 200 1.8 2.0 0.100 133 146 WV-SBO 16 0.500 21.3 200 1.8 2.0 0.100 133 146 WV-SBO 12 0.500 21.0 2500*** 1.9 200 0.105 127 124 0.105 127 140 WV-SBO 10 <</td> <td>231</td> <td>4V-SBO</td> <td></td> <td>0.500</td> <td>34.4</td> <td>**0569</td> <td>2.7</td> <td>2873</td> <td>0.478</td> <td>8</td> <td>117</td> <td>132</td> <td></td>	WV-SBO 17 0.550 30.6 5223 1.7 2288 0.193 110 115 WV-SBO 18 0.550 32.8 7800** 2.9 298 0.191 106 124 WV-SBO 18 0.370 7.6 645 1.7 775 0.180 123 116 124 WV-SBO 12 0.400 13.3 200 1.7 177 0.100 143 121 WV-SBO 16 0.500 13.3 200 1.8 326 0.100 143 136 WV-SBO 16 0.500 13.3 200 1.8 2.0 0.100 133 146 WV-SBO 16 0.500 21.3 200 1.8 2.0 0.100 133 146 WV-SBO 12 0.500 21.0 2500*** 1.9 200 0.105 127 124 0.105 127 140 WV-SBO 10 <	231	4V-SBO		0.500	34.4	**0569	2.7	2873	0.478	8	117	132	
tv-SBO 37 0.550 32.8 7800*** 2.9 2988 0.191 tv-SBO 18 0.370 9.5 516 2.4 210 0.180 tv-SBO 17 0.370 9.5 516 2.4 210 0.180 tv-SBO 12 0.400 8.3 370 1.7 175 0.100 tv-SBO 12 0.400 8.3 370 1.8 278 0.160 tv-SBO 16 0.500 13.3 2060 1.8 1.250 0.100 tv-SBO 16 0.500 21.3 3553*** 1.9 2083 0.160 tv-SBO 14 0.500 21.3 3553*** 1.9 2083 0.160 tv-SBO 14 0.500 21.3 3553*** 1.9 2083 0.160 tv-SBO 16 0.500 21.3 3553*** 1.9 2083 0.160 tv-SBO 16 0.500	W-SBO 37 0.550 32.8 7800+4 2.9 298 0.191 105 124 W-SBO 18 0.370 9.5 516 2.4 210 0.180 123 116 W-SBO 17 0.370 7.6 645 1.8 276 0.180 123 116 124 W-SBO 18 0.500 10.5 728 1.8 286 0.100 143 181 W-SBO 18 0.500 13.3 206 1.8 286 0.100 143 146 W-SBO 18 0.500 21.3 2500+4 1.9 2030 0.275 120 178 W-SBO 24 0.500 21.3 353+4 1.9 209 0.275 120 178 W-SBO 22 0.500 21.0 260 22.1 140 0.250 141 141 142 W-SBO 22 0.500 12.1 644 </td <td>232</td> <td>4V-SBO</td> <td></td> <td>0.550</td> <td>30.6</td> <td>5223</td> <td>1.7</td> <td>2288</td> <td>0.193</td> <td>011</td> <td>115</td> <td>5</td> <td></td>	232	4V-SBO		0.550	30.6	5223	1.7	2288	0.193	011	115	5	
tv-SBO 18 0.370 9.5 516 2.4 210 0.186 tv-SBO 17 0.370 7.6 645 1.8 278 0.162 tv-SBO 12 0.400 8.3 370 1.7 175 0.100 tv-SBO 16 0.550 10.5 728 1.8 278 0.100 tv-SBO 16 0.500 21.3 2060 1.8 1250 0.100 tv-SBO 16 0.690 21.3 2060 1.8 1250 0.100 tv-SBO 16 0.690 21.3 2060 1.9 2083 0.275 tv-SBO 12 30.6 * 2.0 401 0.163 0.163 tv-SBO 12 0.500 21.0 825 2.0 401 0.143 tv-SBO 10 0.500 21.0 8.0 10.5 11.1 57 0.000 tv-SBO 10 0.410	ty-SBO 18 0.370 9.5 516 2.4 210 0.180 123 116 ty-SBO 17 0.400 8.3 370 1.7 175 0.162 129 131 ty-SBO 16 0.500 13.3 2060 1.8 326 0.100 143 136 ty-SBO 16 0.500 13.3 2060 1.8 326 0.100 143 136 ty-SBO 16 0.500 21.3 353*** 1.9 2083 0.275 133 146 ty-SBO 16 0.500 11.8 825 2.0 401 0.127 120 127 ty-SBO 22 0.500 11.8 825 2.0 401 0.127 120 127 ty-SBO 22 0.500 11.8 825 2.0 401 0.126 11.7 11.7 ty-SBO 22 0.500 12.7 644 1.2 <t< td=""><td>233</td><td>4V-SBO</td><td></td><td>0.550</td><td>32.8</td><td>7800**</td><td>0</td><td>800</td><td>101.0</td><td>351</td><td>101</td><td>110</td><td></td></t<>	233	4V-SBO		0.550	32.8	7800**	0	800	101.0	351	101	110	
tv-SBO 17 645 1.8 278 0.162 tv-SBO 12 0.400 8.3 370 1.7 175 0.162 tv-SBO 12 0.400 8.3 370 1.7 175 0.162 tv-SBO 16 0.550 10.5 728 1.8 326 0.160 tv-SBO tb 0.650 21.3 3553*** 1.9 2083 0.160 tv-SBO tb 0.650 21.3 3553*** 1.9 2083 0.275 tv-SBO tb 0.650 21.3 3553*** 1.9 2083 0.275 tv-SBO tb 0.650 21.3 3553*** 1.9 2083 0.160 tv-SBO tb 0.650 21.6 4.6 0.500 0.160 0.160 tv-SBO 10 0.500 12.7 6.4 1.2 1.1 0.106 tv-SBO 10 0.410 23.9 3927	4V-SBO 17 0.370 7.6 645 1.8 278 0.162 129 131 121 4V-SBO 12 0.400 8.3 370 1.7 175 0.100 143 121 4V-SBO 16 0.500 13.3 2050 1.8 326 0.100 143 121 4V-SBO 16 0.690 21.3 2050 1.8 326 0.150 133 146 4V-SBO 45 0.690 21.3 2050 1.9 2083 0.275 120 178 121 4V-SBO 45 0.500 28.0 5500** 1.9 2083 0.275 121 127 147 4V-SBO 12 0.500 11.8 825 2.0 401 0.126 121 117 4V-SBO 12 0.500 12.7 644 1.2 373 0.05 124 149 4V-SBO 16 0.410	234	4V-SBO		0.370	9.5	516	1	210	180	201	136	100	
tv-sbo 12 0.400 8.3 370 1.7 175 0.100 tv-sbo 16 0.550 10.5 728 1.8 326 0.100 tv-sbo 18 0.500 13.3 2060 1.8 1250 0.160 tv-sbo 45 0.690 21.3 3553*** 1.9 2083 0.275 tv-sbo 45 0.690 21.3 3553*** 1.9 2083 0.275 tv-sbo 45 0.690 21.3 3553*** 1.9 2083 0.275 tv-sbo 45 0.500 11.8 825 2.0 401 0.165 tv-sbo 22 0.500 11.8 825 2.0 401 0.143 tv-sbo 32 0.500 12.7 644 1.2 373 0.052 tv-sbo 10 0.410 23.9 3927 1.1 24 0.106 tv-sbo 16 0.410	tV-SBO 12 0.400 8.3 370 1.7 175 0.100 113 121 tV-SBO 16 0.550 10.5 728 1.8 326 0.100 143 121 tV-SBO 18 0.500 13.3 2060 1.8 1250 0.160 143 151 tV-SBO 45 0.690 21.3 2060 1.8 20 1.8 1250 178 179 2090 0.150 118 178 178 178 178 178 178 178 178 178 178 179 179 179 171	235	4V-SBO		0.370	7.6	645	1.8	278	0.162	32	131	148	
tv-sbo 16 0.550 10.5 728 1.3 326 0.100 tv-sbo 15 0.500 13.3 2060 1.9 2083 0.160 tv-sbo ts 0.690 21.3 3553*** 1.9 2083 0.275 tv-sbo to 0.875 30.6 * * 2.0 3270 0.275 tv-sbo to 0.600 28.0 28.0 5500** 1.9 2083 0.275 tv-sbo 12 0.500 11.8 825 2.0 401 0.165 tv-sbo 12 0.500 11.8 825 2.0 401 0.143 tv-sbo 12 0.500 12.7 644 1.2 1191 0.205 tv-sbo 10 0.410 8.0 12.7 644 1.2 1.1 1.1 1.2 0.005 tv-sbo 10 0.410 19.4 2730 2.4 1.23 0.006 <td>tV-SBO 1.6 0.550 10.5 728 1.8 326 0.100 143 136 tV-SBO 1.8 0.500 13.3 2060 1.8 1250 0.160 133 146 tV-SBO 45 0.690 21.3 3553*** 1.9 2083 0.275 150 178 146 tV-SBO 40 0.875 30.6 * * 2.0 3270 0.160 133 146 tV-SBO 1.2 30.6 * 2.0 401 0.160 127 127 tV-SBO 2.2 0.500 11.8 825 2.0 401 0.163 143 147 169 tV-SBO 1.2 2.0 401 0.165 2.460 2.2 401 0.165 149 149 tV-SBO 1.0 0.410 8.0 1.0 1.1 373 149 tV-SBO 1.0 0.410 23.9 3927 <t< td=""><td>236</td><td>W-SBO</td><td></td><td>0.400</td><td>8.3</td><td>370</td><td>1.7</td><td>175</td><td>0.100</td><td>113</td><td>121</td><td>127</td><td></td></t<></td>	tV-SBO 1.6 0.550 10.5 728 1.8 326 0.100 143 136 tV-SBO 1.8 0.500 13.3 2060 1.8 1250 0.160 133 146 tV-SBO 45 0.690 21.3 3553*** 1.9 2083 0.275 150 178 146 tV-SBO 40 0.875 30.6 * * 2.0 3270 0.160 133 146 tV-SBO 1.2 30.6 * 2.0 401 0.160 127 127 tV-SBO 2.2 0.500 11.8 825 2.0 401 0.163 143 147 169 tV-SBO 1.2 2.0 401 0.165 2.460 2.2 401 0.165 149 149 tV-SBO 1.0 0.410 8.0 1.0 1.1 373 149 tV-SBO 1.0 0.410 23.9 3927 <t< td=""><td>236</td><td>W-SBO</td><td></td><td>0.400</td><td>8.3</td><td>370</td><td>1.7</td><td>175</td><td>0.100</td><td>113</td><td>121</td><td>127</td><td></td></t<>	236	W-SBO		0.400	8.3	370	1.7	175	0.100	113	121	127	
tv-SBO 18 0.500 13.3 2060 1.8 1250 0.160 tv-SBO ty-SBO to 0.690 21.3 3553*** 1.9 2083 0.275 tv-SBO to 0.690 21.3 3553*** 1.9 2083 0.275 tv-SBO to 0.877 30.6 * * 2.0 3270 0.275 tv-SBO 1.2 0.500 11.8 825 2.0 401 0.275 tv-SBO 1.2 0.500 11.8 825 2.0 401 0.165 tv-SBO 1.2 2460 2.1 1246 0.143 0.200 tv-SBO 1.2 2460 2.2 1191 0.200 tv-SBO 1.0 0.410 8.0 105 1.1 57 0.000 tv-SBO 14 0.410 19.4 2730 2.4 123 0.060 tv-SBO 18 0.550 27.6 6735 27.7 1400 </td <td>tv-sbo 18 0.500 13.3 2060 1.8 1250 0.160 13 146 tv-sbo ty-sbo ty-sbo 21.3 353*** 1.9 2083 0.275 150 178 tv-sbo ty-sbo 54 0.500 28.0 5500** 1.9 2083 0.275 150 178 tv-sbo 54 0.500 12.8 825 2.0 401 0.165 127 127 tv-sbo 12 260 21.0 2619 2.2 1191 0.163 147 169 tv-sbo 32 0.500 12.7 644 1.2 373 0.052 174 149 tv-sbo 10 0.410 23.9 3327 1.1 57 0.000 125 141 tv-sbo 14 0.410 19.4 2730 2.4 1233 0.060 114 137 tv-sbo 14 0.410 19.4 2730<!--</td--><td>237</td><td>4V-SBO</td><td></td><td>0.550</td><td>10.5</td><td>728</td><td>1.3</td><td>38</td><td>00100</td><td>142</td><td>136</td><td>S. C.</td><td></td></td>	tv-sbo 18 0.500 13.3 2060 1.8 1250 0.160 13 146 tv-sbo ty-sbo ty-sbo 21.3 353*** 1.9 2083 0.275 150 178 tv-sbo ty-sbo 54 0.500 28.0 5500** 1.9 2083 0.275 150 178 tv-sbo 54 0.500 12.8 825 2.0 401 0.165 127 127 tv-sbo 12 260 21.0 2619 2.2 1191 0.163 147 169 tv-sbo 32 0.500 12.7 644 1.2 373 0.052 174 149 tv-sbo 10 0.410 23.9 3327 1.1 57 0.000 125 141 tv-sbo 14 0.410 19.4 2730 2.4 1233 0.060 114 137 tv-sbo 14 0.410 19.4 2730 </td <td>237</td> <td>4V-SBO</td> <td></td> <td>0.550</td> <td>10.5</td> <td>728</td> <td>1.3</td> <td>38</td> <td>00100</td> <td>142</td> <td>136</td> <td>S. C.</td> <td></td>	237	4V-SBO		0.550	10.5	728	1.3	38	00100	142	136	S. C.	
tv-SBO t5 0.690 21.3 3553*** 1.9 2063 0.275 tv-SBO to 0.875 30.6 * 2.0 3270 0.275 tv-SBO to 0.875 30.6 * 2.0 3270 0.275 tv-SBO to 0.500 11.8 825 2.0 401 0.126 tv-SBO 12 0.500 11.8 825 2.0 401 0.126 tv-SBO 12 2460 2.1 1246 0.143 0.200 tv-SBO 10 0.500 12.7 644 1.2 373 0.052 tv-SBO 10 0.410 8.0 105 1.1 57 0.000 tv-SBO 14 0.410 19.4 2730 2.4 123 0.060 tv-SBO 48 0.550 27.6 6735 3723 0.060	tv-sbo t5 0.690 21.3 3553*** 1.9 2063 0.275 150 178 tv-sbo to 0.875 30.6 * 2.0 3270 0.275 150 178 tv-sbo to 0.500 28.0 5500** 1.9 2063 0.275 120 127 127 tv-sbo 12 0.500 11.8 825 2.0 401 0.163 147 167 169 tv-sbo 22 0.500 21.0 2619 2.2 1191 0.163 147 169 tv-sbo 32 0.500 21.0 2619 2.2 1191 0.200 125 149 tv-sbo 10 0.410 8.0 10.5 1.1 57 0.000 125 144 tv-sbo 14 0.410 23.9 3927 1.2 4100 0.459 95 137 tv-sbo 48 0.550 27.6	238	4V-SBO		0.500	13.3	2060	1.8	1250	0-160	22.	346	24.5	
tv-SBO to 0.875 30.6 * 2.0 3270 0.270 tv-SBO 54 0.500 28.0 5500*** 1.9 2090 0.165 tv-SBO 12 0.500 11.8 825 2.0 401 0.128 tv-SBO 12 2460 2.1 1246 0.143 0.143 tv-SBO 32 0.500 12.7 644 1.2 373 0.052 tv-SBO 10 0.410 8.0 105 1.1 57 0.000 tv-SBO 14 0.410 19.4 2730 2.4 123 0.060 tv-SBO 14 0.410 19.4 2730 2.4 123 0.080 tv-SBO 16 0.550 27.6 6735 3.723 0.050	tv-sbo to 0.875 30.6 * 2.0 3270 0.270 120 127 tv-sbo 54 0.500 28.0 5500** 1.9 2090 0.165 121 117 tv-sbo 12 0.500 11.8 825 2.0 401 0.165 121 117 165 tv-sbo 22 0.500 11.8 825 2.0 401 0.183 147 169 tv-sbo 22 0.500 21.0 2619 2.2 1191 0.183 149 169 tv-sbo 32 0.500 12.7 644 1.2 373 0.052 174 149 tv-sbo 10 0.410 8.0 105 1.1 57 0.000 133 136 tv-sbo 14 0.410 19.4 2730 2.4 1233 0.060 114 137 tv-sbo 48 0.550 27.6 6735 <t< td=""><td>239</td><td>4V-SBO</td><td></td><td>0.690</td><td>21.3</td><td>3553**</td><td>1.9</td><td>2083</td><td>0.275</td><td>150</td><td>178</td><td>8 2</td><td></td></t<>	239	4V-SBO		0.690	21.3	3553**	1.9	2083	0.275	150	178	8 2	
ty-SBO 54 0.500 28.0 5500*** 1.9 2090 0.155 ty-SBO 12 0.500 11.8 825 2.0 401 0.126 ty-SBO 12 24.6 24.6 27.2 11.9 0.143 ty-SBO 12 24.6 27.0 401 0.143 ty-SBO 12 64.4 1.2 373 0.052 ty-SBO 10 0.410 8.0 105 1.1 57 0.000 ty-SBO 14 0.410 19.4 2730 2.4 1233 0.080 ty-SBO 14 0.410 19.4 2730 2.4 1233 0.080 ty-SBO 14 0.50 27.6 6735 3.723 0.601	tv-SBO 54 0.500 28.0 5500*** 1.9 2090 0.165 121 117 tv-SBO 12 0.500 11.8 825 2.0 401 0.128 147 167 tv-SBO 22 24,0 21.0 24,0 22.2 1191 0.143 147 169 tv-SBO 32 0.500 12.7 644 1.2 373 0.052 174 145 tv-SBO 10 0.410 8.0 105 1.1 57 0.000 133 136 tv-SBO 14 0.410 19.4 2730 1.1 57 0.000 112 141 tv-SBO 14 0.410 19.4 2730 2.4 1233 0.080 114 137 tv-SBO 48 0.550 27.6 6735 5.5 3723 0.601 127 141 tv-SBO 48 0.560 27.6 6735 3723	240	4V-SBO		0.875	30.6	*	5.0	3270	0.270	25	182	144	
tv-sbo 12 0.500 11.8 825 2.0 401 0.128 tv-sbo 22 0.500 16.6 2460 2.1 1246 0.143 tv-sbo 32 0.500 21.0 2619 2.2 1191 0.200 tv-sbo 36 0.500 12.7 644 1.2 373 0.052 tv-sbo 10 0.410 8.0 105 1.1 57 0.000 tv-sbo 40 0.410 23.9 3927 1.5 1514 0.106 tv-sbo 14 0.410 19.4 2730 2.4 1233 0.080 tv-sbo 48 0.560 27.6 6735 5.5 3723 0.601	tv-sbo 12 0.500 11.8 825 2.0 401 0.128 143 153 tv-sbo 22 2460 2.1 1246 0.143 147 169 tv-sbo 32 0.500 21.0 2619 2.2 1191 0.200 125 149 tv-sbo 36 0.500 12.7 644 1.2 373 0.052 174 145 tv-sbo 10 0.410 8.0 105 1.1 57 0.000 133 136 tv-sbo 40 0.410 23.9 3927 1.5 1514 0.106 125 141 tv-sbo 14 0.410 19.4 2730 2.4 1233 0.080 114 137 tv-sbo 48 0.550 27.6 6735 5.5 3723 0.601 127 14; tv-sbo 48 0.560 27.6 6735 3723 0.601 127	241	47-SB0		0.500	28.0	\$500 **	1.9	2090	0.150	121	H	116	
tv-SBO 22 0.500 16.6 2460 2.1 1246 0.143 tv-SBO 32 0.500 21.0 2619 2.2 1191 0.200 tv-SBO 10 0.410 8.0 10.5 1.1 373 0.052 tv-SBO 10 0.410 8.0 105 1.1 57 0.000 tv-SBO 4v-SBO 10 23.9 3927 1.5 1514 0.106 tv-SBO 14 0.410 19.4 2730 2.4 1233 0.080 tv-SBO 16 0.550 27.6 6735 3.723 0.601	tv-sb0 22 0.500 16.6 2460 2.1 1246 0.143 147 169 tv-sb0 32 0.500 21.0 2619 2.2 1191 0.20 125 149 tv-sb0 36 0.500 12.7 644 1.2 373 0.052 174 145 tv-sb0 10 0.410 8.0 105 1.1 57 0.052 174 145 tv-sb0 40 0.410 23.9 3927 1.5 1514 0.106 125 141 tv-sb0 14 0.410 19.4 2730 2.4 1233 0.060 114 137 tv-sb0 48 0.550 27.6 6735 5.5 3723 0.601 127 14. tv-sb0 48 0.560 27.6 6735 5.5 3723 0.601 127 14.	242	4V-SBO		0.500	11.8	825	2.0	401	0.128	142	153	157	
tv-sbo 32 0.500 21.0 2619 2.2 1191 0.200 tv-sbc 36 0.500 12.7 644 1.2 373 0.052 tv-sbc 10 0.410 8.0 105 1.1 57 0.052 tv-sbc 4v-sbc 4v-sbc 3927 1.5 1514 0.106 tv-sbc 14 0.410 19.4 2730 2.4 1233 0.080 tv-sbc 48 0.560 27.6 6735 5.5 3724 0.601	tv-sbo 32 0.500 21.0 2619 2.2 1191 0.200 125 149 tv-sbc 36 0.500 12.7 644 1.2 373 0.052 174 145 tv-sbc 10 0.410 23.9 3927 1.1 57 0.000 133 136 tv-sbc to 0.410 19.4 2730 2.4 1233 0.080 114 137 tv-sbc 48 0.550 27.6 6735 5.5 3723 0.601 127 14);	243	4V-SBO		0.500	16.6	2460	2.1	1246	0.143	747	163	101	
tv-sbc 36 0.500 12.7 644 1.2 373 0.052 tv-sbc 10 0.410 8.0 105 1.1 373 0.052 tv-sbc 10 0.410 23.9 3927 1.5 1514 0.106 tv-sbc 14 0.410 19.4 2730 2.4 1233 0.080 tv-sbc 55 0.530 33.7 9880 7.7 4100 0.459 tv-sbc 48 0.560 27.6 6735 5.5 3723 0.601	tv-sbc 36 0.500 12.7 644 1.2 373 0.052 174 145 tv-sbc 10 0.410 8.0 105 1.1 57 0.052 174 145 tv-sbc to 0.410 23.9 3927 1.5 1514 0.106 125 141 tv-sbc 14 2730 2.4 1233 0.080 114 137 tv-sbc 48 0.550 27.6 6735 5.5 3723 0.601 127 14;	170	4V-SBO		0.500	21.0	2619	5.5	1191	0.500	125	140	153	
tv-SB0 10 0.410 8.0 105 1.1 57 0.000 tv-SB0 to 0.410 23.9 3927 1.5 1514 0.106 tv-SB0 tb 0.410 19.4 2730 2.4 1233 0.080 tv-SB0 55 0.530 33.7 9880 7.7 4100 0.459 tv-SB0 tb 0.560 27.6 6735 5.5 3723 0.601	tv-sbo 10 0.410 8.0 105 1.1 57 0.000 133 136 tv-sbo tv-sbo to 0.410 23.9 3927 1.5 1514 0.106 125 141 tv-sbo tv-sbo 14 2730 2.4 1233 0.080 114 137 tv-sbo 55 0.530 33.7 9880 7.7 4100 0.459 95 135 tv-sbo tb 0.560 27.6 6735 5.5 3723 0.601 127 14;	245	17-SEC		0.500	12.7	4109	1.2	373	0.052	174	145	170	
tv-sbo to 0.410 23.9 3927 1.5 1514 0.106 tv-sbo tv-sbo 1t 0.410 19.4 2730 2.4 1233 0.080 tv-sbo 55 0.530 33.7 9880 7.7 4100 0.459 tv-sbo 48 0.560 27.6 6735 5.5 3723 0.601	tv-sb0 to 0.410 23.9 3927 1.5 1514 0.106 125 141 tv-sb0 14 2730 2.4 1233 0.080 114 137 tv-sb0 55 0.530 33.7 9880 7.7 4100 0.459 95 135 tv-sb0 48 0.560 27.6 6735 5.5 3723 0.601 127 14.	510	4V-SBO		0.410	8.0	105	1.1	57	00000	133	136	143	
4V-SBO 14 0.410 19.4 2730 2.4 1233 0.080 4V-SBO 55 0.530 33.7 9880 7.7 4,100 0.459 4V-SBO 48 0.560 27.6 6735 5.5 3723 0.601	4V-SBO 14 0.410 19.4 2730 2.4 1233 0.080 114 137 4V-SBO 55 0.530 33.7 9880 7.7 4100 0.459 95 135 4V-SBO 48 0.560 27.6 6735 5.5 3723 0.601 1.27 14;	247	4V-SBO		0.410	23.9	3927	1.5	1514	0,106	125	וקו	152	
4V-SBO 55 0.530 33.7 9880 7.7 4.100 0.459 4V-SBO 48 0.560 27.6 6735 5.5 3723 0.601	4V-SBO 55 0.530 33.7 9880 7.7 4100 0.459 55 135 4V-SBO 48 0.560 27.6 6735 5.5 3723 0.601 127 14.	5 7 8	4V-SBO		0.410	19.4	2730	2.4	1233	0,080	114	137	ואפר	
4V-SBO 48 0.560 27.6 6735 5.5 3723 0.601	4v-sbo 48 0.560 27.6 6735 5.5 3723 0.601 127 14.	249	4V-SBO		0.530	33.7	9880	7.7	100	0.450	90	125	116	
		250	4V-SBO		0.560	27.6	6735	5.5	3723	0.601	121	्रेन वित्त	15,5	

* Instrumentation failure. ** Bamboo clump failed but vehicle immobilized on top of clump.

Table B3

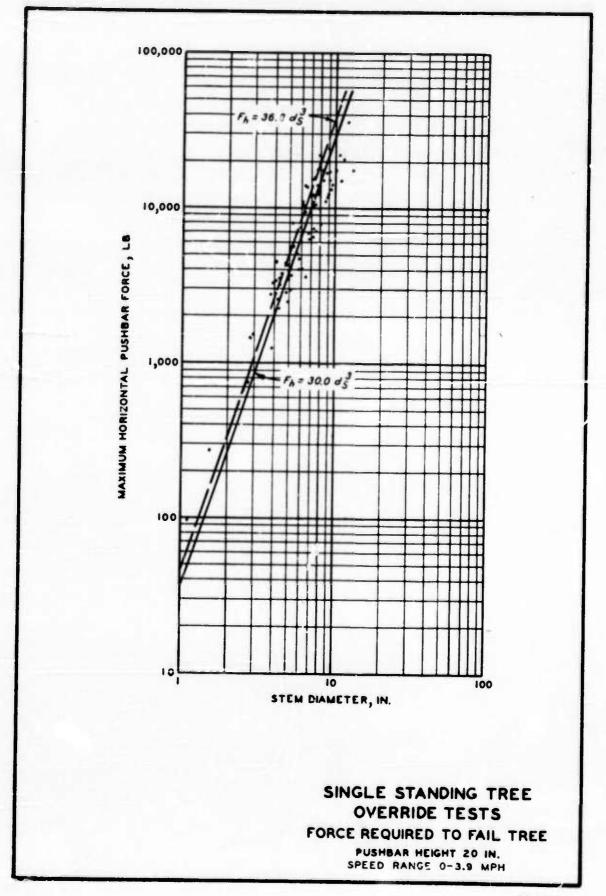
Summing of Data and Test Results, Multiple free Override Tests

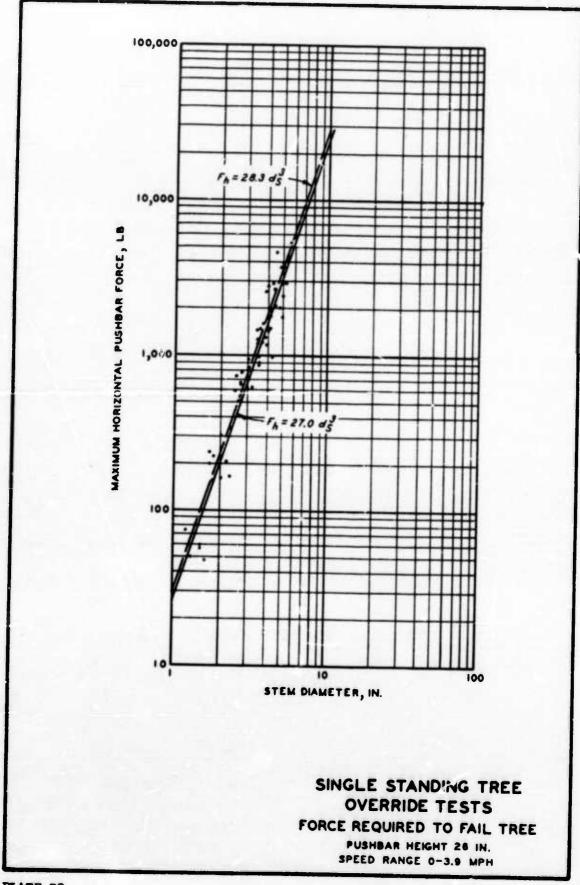
Part															Distance		Menoured Values	for Teats	Compared Value	'salues								
Fig. 5/11/65 26 11 Oak 2.1 3.5 2.9 2.9 2.4 2.4. 1.5 37.0 0.0 19.647 2.9 13.64 2.9	Test.	•	Teat	Push- bar Beight in.		1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0		Ster,			Press	Struc- tural Cell. Sins	Ve-	Length of Test Course	Computed from from Track Revolu- tion Count ft		Work Re- quired to Fal: Trees	Forse Rev. Quired to Fail Trees It	Hork Re-	Avg Porce Re- quired to Fail Irees	Max Longi- tudinal Accel- eration	7. Av. 6-10.	Cone In 12-in.	dex 18- to Myer	20 0	10.01	2	ure Content Soil seint to to la to 12-in 15-in Layer Layer
Fig. 5/11/6														N37 3	/4-ton Ch	rgo Truc	651											
Fig. 5/11/65 56 69 Oak 1.3 4.4 2.6 16 5.6 6.5 5.9 1.5 5.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 1.5 2.0 0 0.5 1.3 7.7 1.5 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.5 1.3 7.7 1.5 2.0 0 0.	25	212	\$/11/6	%	=	*	2.7	Š	6.8	8	5.4	2.4	1.5	37.0	•	•	10.67	533	2 8 9	3	-	d						
Fire Sylly65 See State	9%	E-15	5/11/65	%	æ	8	1.3	4	2.6	18	5.8	85.9	1.5	26.0	•		-	4	13,004	5,5		8	106	901			6.0	7
Maile Sylry(s) Sylry S	65	9T-I	5/11/65	%	60	ONE	Ci.	4.1	69	8	5.9	8	9	6			77116	7,00	200	165	•	22	ක්	93			8.0	2.5
Number 6 277 64 277 64 277 64 277 64 277 64 778	-4	34.5A.9	8/21/64	×	43	Pine		ari ev		o	8	5		2			21,231	1011	15,162	722	•	16	119	100			3.4	m
Mailer 8/27/64 26 53 Pitte 0.7 3.5 1.6 12 3.4 13.0 2.000 17.0 1.0 26,103 3.9 20,114 262 0.9 47.5 6.0 2.000 2.4 2.0 2.4 2.5 2.0 2.4 2.5 2.5 2.5 2.4 2.5 2.5 2.4 2.4 2.5 2.5 2.4 2.4 2.5 2.5 2.4 2.4 2.5 2.5 2.4 2.4 2.5 2.5 2.4 2.4 2.5 2.5 2.4	CV.	W34-5	8/27/6	%	X 2	Ma		3.8		1				5,0	41.5	9.6	6,738	18.	2,0%	136		200	237	•				•
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Much-1 11/16/64			5/3/5	9	2	2		0	3.1	R	4	19.6	% . ⊙	24.5	χ. .4.	7.5	30,600	1249	21,486	FLE		318	356					
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MAGN-12 11/16/64 26 17 Price 1.8 6.7 b.6 b.1 6.6 29.3 3.6 6.2.0 75.4 17.8 226/720 25/57 115/272 145/9 0.55 339 b.65 513 CLANG. CLANG. MAGN-12 11/16/64 26 11 Price 3.6 8.8 6.1 b.7 7.8 34.9 2.5 52.0 60.0 20.0 231.920 4460 133.36 25/5 0.90 134 169 8 6.8 71 Price 3.5 6.8 b.2 b.2 b.2 5 5.0 60.0 20.0 231.920 4460 133.36 25/5 0.90 134 169 63 713 ML ML ML MAGN-10 11/16/64 26 77 Price 3.5 6.9 b.2 b.1 6.3 26/3 b.1 25.0 35.0 23.6 74,500 25/3 19/5,91 183 0.95 371 683 713 ML ML ML ML MAGN-10 11/16/64 36 21 Price 1.7 5.6 3.5 22 4.8 21.5 3.5 50.0 7.9 144,000 25/3 19/5 0.95 13/6 0.95 21/3 1/6/64 36 21 Price 2.5 6.0 b.2 37 7.8 32.9 9.4 232.0 • 111,16/64 36 21/3 52 5.9 1.40 186 330 466 CLANG. CLANG. MAGN-10 11/16/64 36 51 Price 2.5 6.5 b.3 36 7.0 31.3 10.1 25/4.0 • 141,000 1705 24/9 18/5 22 13/6 0.95 14/6 14/6 14/6 14/6 14/6 14/6 14/6 14/6	6 -	MSA-3	11/16/64	%	杰	Pine			6.4	18	en	26.3	0.4	122.0	125.6		9		0									
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Muchanto 11/16/64 26 18 Price 1.5 9.3 8.5 39 6.8 30.4 2.6 74.5 79.0 7.0 324,160 1443 196,931 1938 0.95 371 683 713 ML ML MANANIO 11/16/64 26 7 Price 1.5 6.9 8.5 81 6.3 80.4 2.6 74.5 79.0 7.0 324,160 2938 49,141 1817 0.70 442 687 689 ML ML MANANIO 11/16/64 38 43 Price 2.5 6.0 8.4 37 7.8 32.9 9.8 232.0 • 411,000 1705 289,890 1077 0.00 186 330 466 CLML CLML MANANI 11/16/64 38 51 Price 2.5 6.5 8.3 36 7.0 31.3 10.1 294.0 • 414,000 1500 271,335 923 1.40 186 330 466 CLML CLML CLML	0	WSA-12		%	1	Pine	3.6	8.8	6.1	(-n	7.8	6.4	5.5	0 04	0 09		CCO, 150		115,272	1659	0.75	32	24					13.8 15.3
Mach-10 11/15/64 26 7 Pine 3-5 6-9 4-5 41 6-3 28-3 4-1 25-0 35-0 23-6 74-500 29-92 4-5-414 1817 0.70 44-2 687 669 HL ML MACH-3 11/15/64 26 27 Pine 1-7 5-6 3-5 3-5 3-6 25-5 6-0 7-5 147,000 28-49 86,552 15-90 0.95 287 4-7 904 8. MACH-3 11/15/64 3-9 4-3 3-1 7-4 32-9 9-4 25-2-0 9-4 11/10/00 17-5 28-9-9-9-9-9-9-9-9-9-9-9-9-9-9-9-9-9-9-9	-	M24-10		×	18	P 20			5.5			1.05	9.0	1			134.960		133,380	2565	8	#						15.4 1.8
Manual 11/16/64 26 27 Pine 1.7 5.6 3.5 32 4.8 21.5 3.5 55.0 60.0 7.9 147,000 2649 06,552 15/96 0.70 142 687 669 NL NL NL NAMA-3 11/16/64 38 43 Pine 2.5 6.0 4.4 37 7.4 32.9 9.4 232.0 • 411,000 1765 249,630 1077 0.40 186 330 466 0L-NL CL-NL NAMA-3 11/16/64 38 51 Pine 2.5 6.5 4.3 38 7.0 31.3 10.1 294.0 • 144,000 1500 271,335 923 1.40 186 330 466 0L-NL CL-NL	2	W34-10		8	-	715		0.9				9			0.6		007°4		136,931	1638	0.95	37.1				Ä		14.2 15.1
11/16/64 38 51 Prime 2.5 6.0 4.4 37 7.4 32.9 9.4 232.0 • 4.11,000 1705 249,830 1077 0.40 186 330 466 CL-ML CL-ML 11/16/64 38 51 Prime 2.5 6.5 4.3 38 7.0 31.3 10.1 294.0 • 441,000 1705 249,830 1077 0.40 186 330 466 CL-ML CL-ML	(4)	W.ABA		×	. 8							9	7.0	52.0	35.0	23.0	74,600		42,624	1817	0.70	244						•
MASSA-3 11/16/64 38 51 Prime 2.5 6.5 4.3 38 7.0 31.3 10.1 294.0 • 144.000 1765 249,830 1077 0.60 186 330 466 CL-4C.	5	W.34-3		3 %	¥ 4		1.1	0.0	3.5		_	21.5	3.5	55.5	0.00		47,000		UB,552	15%	み。	287	1	70				4. 0.70
31.3 10.1 24.0 . 144,000 1500 271,335 923 1.40 186 330 466 C. M.		W.S.A.	11/16/6	3 %	7 5			0.0				6.9		232.0			111,000			1077	0.00	156						
THE PERSON NAMED IN COLUMN TO PERSON NAMED I			- / ap / ap	2	75			6.5						0.40		•	44,000		71,335	83	1.40	186				3		

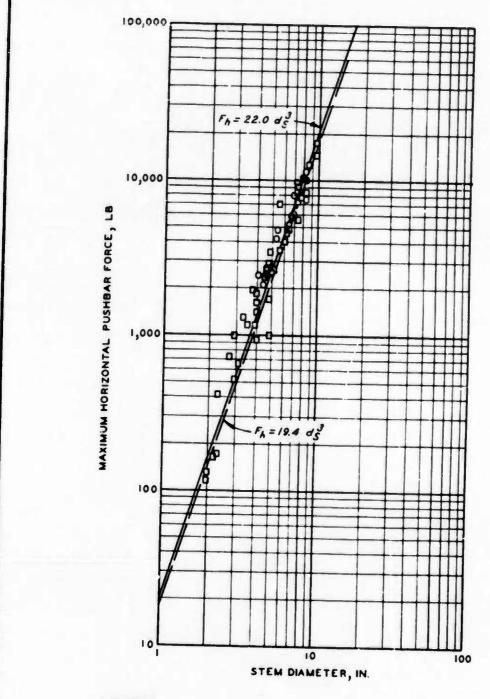
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Table B

lest No.	Tree (Common Name)	Stem Diameter in.	Distance ft	Test No.	Tree (Common Name)	Stem Diameter in.)istance ft
	20-in. Pus	hbar Height			26-in. Pu.	shtar Height	
34	Hieng	13.0	6.70	1	Pine	1.8	3.70
35 36	Hieng	5.0	3.90	5	Pine	4.1	4.20
36	Hieng	7.2	4.30		Pine	2.7	6.10
37	Hieng	6.7	7.75	7 8	Pine	4.0	4.00
38	Hiere	7.4	4.10		Pine	4.5	5.40
39	Hieng	5.8	5.50	9	Pine	3.5	3.50
40	Hieng	4.8	2.10	11	Pine	4.5	5.20
41	Hieng	8.0	4.30	12	Pine	4.1	5.40
42	Hieng	6.4	4.70	13 14	Pine	3.9	6.20
47	Hieng Hieng	6.1 5.0	2.20 3.30	16	Pine Pine	3.5	5.80
48	Hieng	7.5	8.10	17	Pine	3.6	5.80
49	Hieng	8.8	4.10	19	Pine	2.3	4.80
50	Hieng	10.0	5.50	20	Pine	2.7	7.10
51 52	Hieng Hieng	10.7 9.1	6.50 4.80	21 22	Pine Pine	5.0 3.2	6.90
54	Hieng	5.1	6.70		Pine	5.3	4.90
55	Hieng	4.8	3.50	23 26	Pine	2.2	6.50
56	Hieng	4.3 5.8	3.20	27	Pine	3.4	5.40
57 58	Hieng Hieng	6.0	2.80 5.40	30 31	Oak Oak	1.5	6.60
50	Hieng	3.9	2.60	34	Oak	2.3	5.40
59 61	Hieng	4.9	3.30	38	Oak	3.7	6.60
62	Hieng	2.7	6.80	39	Oak	5.2	5.30
16		6.1	6.00	40			
17	Pine Pine	5.1	5.30	40	Oak Oak	5.0 3.9	7.30
10	Pine	5.5	5.40	42	Oak	2.5	4.20
19	Pine	7.9	5.60		Oak	5.3	7.70
20	Pine	6.4	5.50	43 44	Oak	4.0	5.10
21.	Pine	4.3	8.00				
22	Pine	5.1	6.40			Average distance	5.71
23	Pine Pine	7.1 8.3	7.70 8.60		32-in. Pu	shbar Height	
25	Pine	4.3	7.10				
25	Pine	4.9	4.30	1	Hieng	2.0	4.40
23	Pine	8.0	7.00	2	Fieng	2.3	4.25 6.15
59	Pine	7.0	6.00	3	Hieng Hieng	2.9 7.3	5.75
29	Pine	7.9	6.40		Hieng	4.0	4.60
30	Pine	7.3	5.50	5	Hieng	3.1	7.60
31	Pine	7.6	6.80				
32	Pine	6.4	5.20	7 8	Hieng	2.2	5.15
34	Pi.ne	0.0	9.40	9	Hieng Hieng	4.7	6.50
37	rine	1.6	6.00	11	Hieng	4.6	8.20
38	Pine	6.6	9.00	12	Hieng	6.4	7.50
40	Pine	3.6	9.20	13	Hieng	5.6	7.10
147	Pine	7.1	6.00		11.5	8.4	
149	Pine	7.9	5.70	14	Hieng	6.4	7.70
153	Pine	9.3	6.40	15 16	Hieng	4.0	5.30 8.50
154	Pine	9.0	7.40	17	Hieng Hieng	6.1	3.00
				18	Hieng	7.4	8.50
		Average distance	5.67	19	Hieng	4.8	4.00
				20 21	Hieng	4.9 5.0	8.70
				26	Hieng Hieng	2.9	4.00
				27	Hieng	4.0	3.80
				28	Hieng	5.1	5.00
				29	Hieng	3.3	5.00
				30		2.7	7.60
				31	Hieng Hieng	3.9	3.20
				32	Hieng	4.0	7.00
				3-		7.0	
				33	Hierg	9.7	4.50
				32 33	Hierg	9.7	4.50





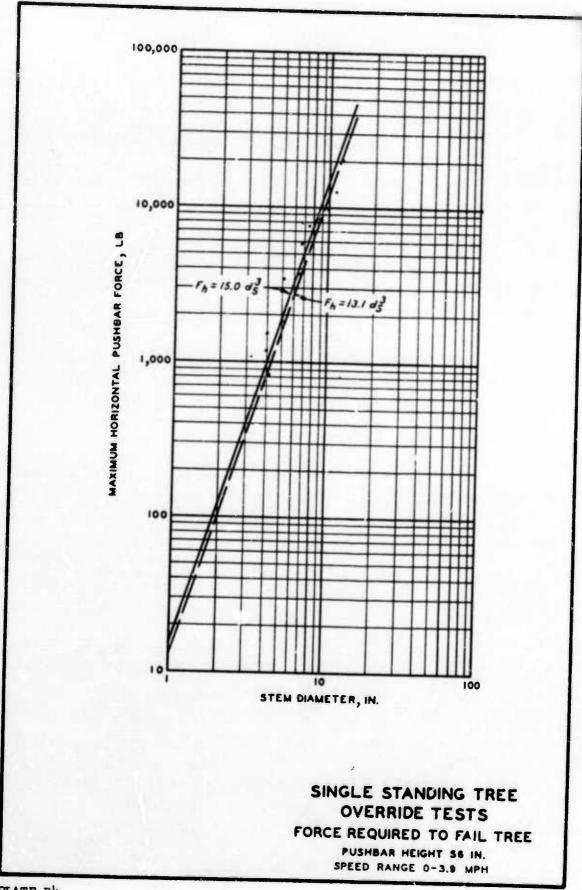


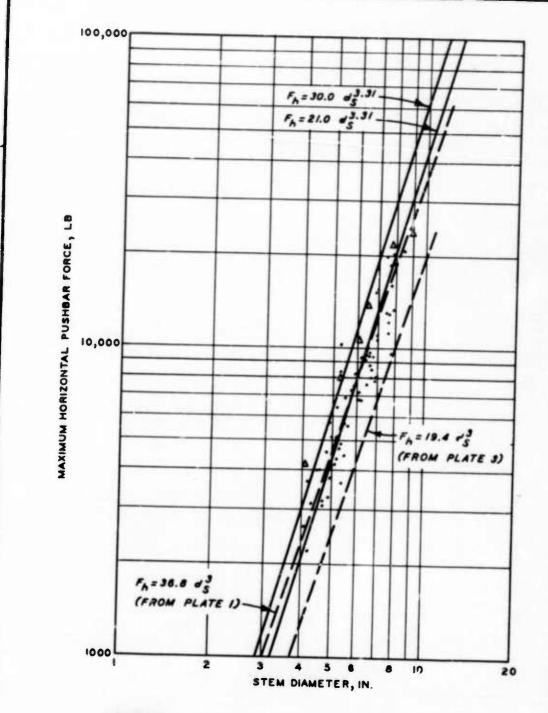
0 32-IN. PUSHBAR HEIGHT O 36-IN. PUSHBAR HEIGHT

SINGLE STANDING TREE OVERRIDE TESTS

FORCE REQUIRED TO FAIL TREE

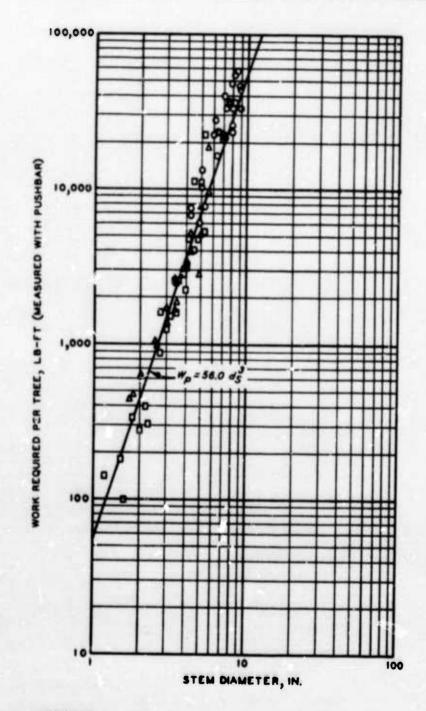
PUSHBAR HEIGHT 32 AND 38 IN. SPEED RANGE 0-3.9 MPH





- 20-IN. PUSHBAR HEIGHT 38-IN. PUSHBAR HEIGHT

SINGLE STANDING TREE OVERRIDE TESTS FORCE REQUIRED TO FAIL TREE SPEED RANGE 4-17 MPH

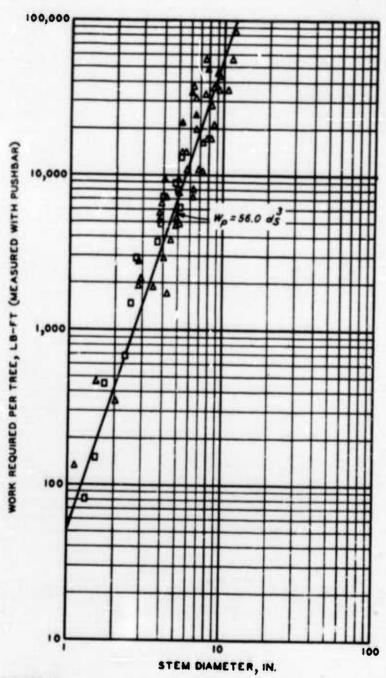


- O NASA MARSHALL SPACE FLIGHT CENTER, MISS., AUG 1964 O NASA MARSHALL SPACE FLIGHT CENTER, MISS., NOV 1964 A EGLIN AFB. FLA., MAY 1965

SINGLE STANDING TREE OVERRIDE TESTS

WORK REQUIRED TO FAIL TREE CONIFERS IN THE UNITED STATES

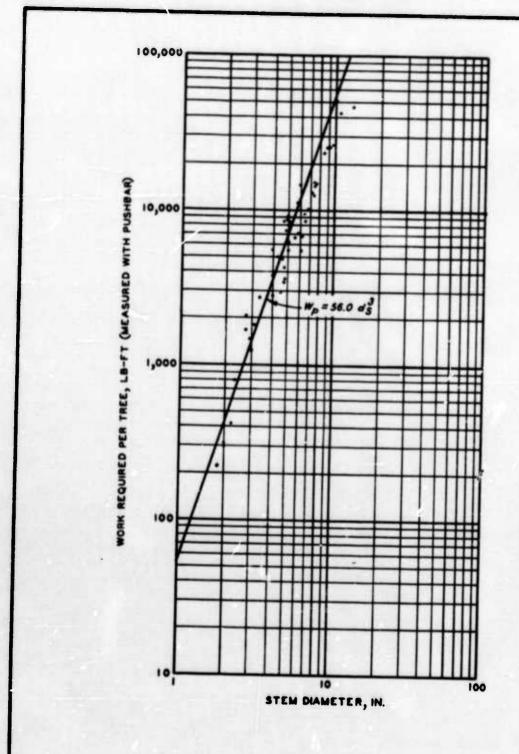
PLATE B6



- Δ EGLIN AFB, FLA., MAY 1965, SPEED RANGE 0-3.9 MPH
- ▲ EGLIN AFB, FLA., MAY 1965, SPEED RANGE 4-12 MPH
- D NASA MARSHALL SPACE FLIGHT CENTER, MISS., AUG 1964, SPEED RANGE 0 - 3.9 MPH

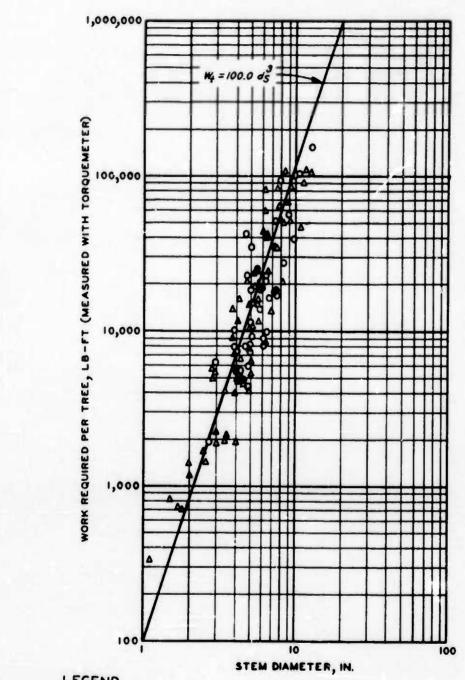
SINGLE STANDING TREE OVERRIDE TESTS

WORK REQUIRED TO FAIL TREE HARDWOODS IN THE UNITED STATES



SINGLE STANDING TREE OVERRIDE TESTS

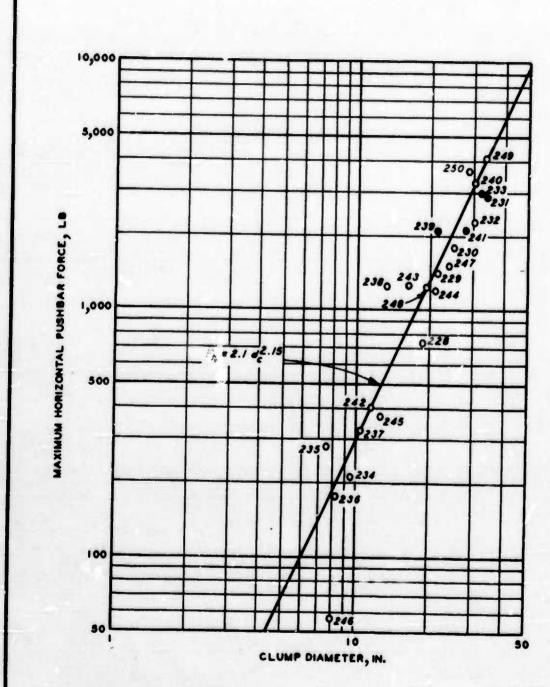
WORK REQUIRED TO FAIL TREE HARDWOODS IN THAILAND



- LEGEND EGLIN AFB, FLA., SPEED RANGE 0 3.9 MPH
- EGLIN AFB, FLA., SPEED RANGE 4 12 MPH
- THAIL AND, SPEED RANGE 0 3.9 MPH

SINGLE STANDING TREE OVERRIDE TESTS

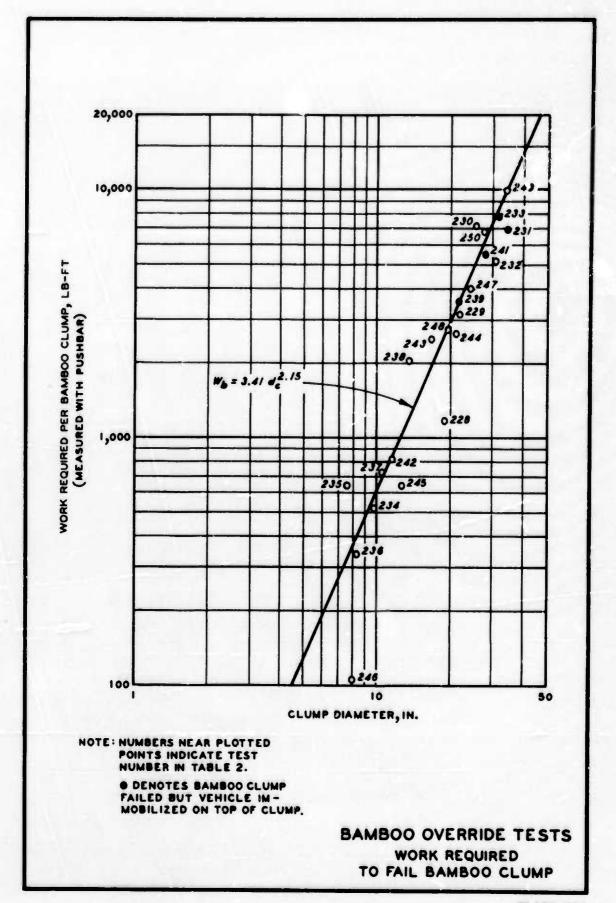
WORK REQUIRED TO OVERRIDE TREE

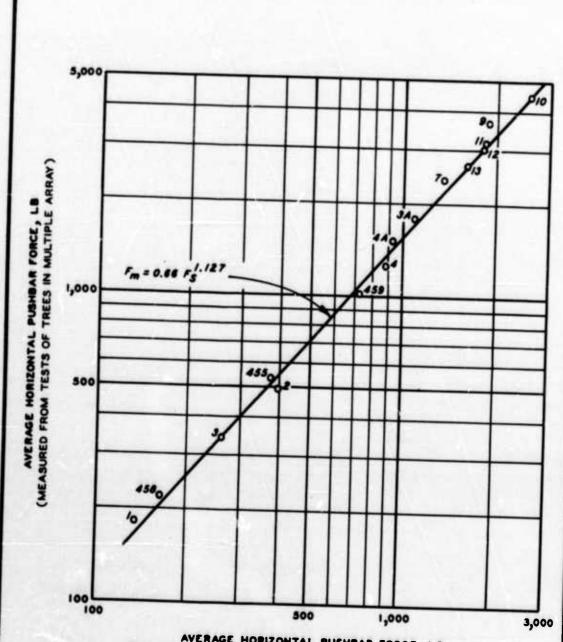


NOTE: NUMBERS NEAR PLOTTED
POINTS INDICATE TEST
NUMBER IN TABLE 2.

DENOTES BAMBOO CLUMP
FAILED BUT VEHICLE IM—
MOBILIZED ON TOP OF CLUMP.

BAMBOO OVERRIDE TESTS
FORCE REQUIRED
TO FAIL BAMBOO CLUMP



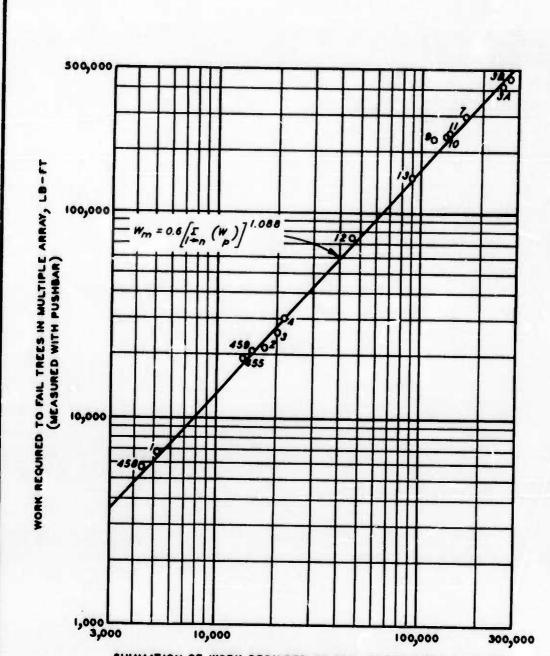


AVERAGE HORIZONTAL PUSHBAR FORCE, LB (COMPUTED FROM RELATIONS ESTABLISHED IN SSTO TESTS)

NOTE: NUMBERS NEAR PLOTTED POINTS INDICATE TEST NUMBER IN TABLE 3.

SSTO INDICATES SINGLE STANDING TREE OVER-RIDE.

MULTIPLE TREE
OVERRIDE TESTS
COMPARISON OF AVERAGE
FORCE REQUIRED TO FAIL TREES
SINGLY AND IN MULTIPLE ARRAY



SUMMATION OF WORK REQUIRED TO FAIL TREES SINGLY, LB-FT (COMPUTED FROM RELATIONS ESTABLISHED IN SSTO TESTS)

NOTE: NUMBERS NEAR PLOTTED POINTS INDICATE TEST NUMBER IN TABLE 3. SSTO INDICATES SINGLE STANDING TREE OVER-RIDE.

MULTIPLE TREE OVERRIDE TESTS

COMPARISON OF WORK REQUIRED TO FAIL TREES SINGLY AND IN MULTIPLE ARRAY

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Donald D. Randolph			
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NASA Marshall Space Flight Center, Miss., Eglin Air Force Base, Fla., Pran Buri, Thailand, and Khon Kaen, Thailand. The general purpose of these tests was to obtain data relating characteristics of longitudinal obstacles to vehicle performance in terms suitable for use in developing that portion of the analytical model for crosscountry performance. The specific purposes were (a) to determine the maximum horizontal force and total work required to override single standing trees of a range of sizes at various speeds and pushbar heights and (b) to determine average horizontal force and total work required to override trees in multiple array. Empirical relations are presented to support the conclusions that pushbar force required to fail trees singly and in multiple array, work required to fail trees singly and in multiple array, and work required to override a single standing tree may be predicted from stem diameter(s). A method is suggested for predicting work required to override trees in multiple array. The results of the tree-felling tests in the Tunguska meteorite area were confirmed, with a single exception noted, and discussed. It is recommended that additional testing be done in areas of soft soil to determine the effect of soil strength on uprooting, and in grass and brush areas to determine the effect of small vegetation on speed.

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